LABORATORY MANUAL IN GENERAL SCIENCE

CLARK

LABORATORY MANUAL

IN

GENERAL SCIENCE

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CLARK'S LABORATORY MANUAL.

W. P. I

PREFACE

THIS *Laboratory Manual* is designed to accompany my *General Science.* The experiments contained in the manual, with the exception of those on Specific Heat, Heats of Fusion and Vaporization, and a few others, can be easily and intelligently made by the average pupil of the second year high school, since little or no mathematics is involved.

The elaborate and quantitative experiments required for college preparation have been entirely omitted. Only such experiments are given as will prove of interest and benefit to the pupils whose formal education ends with the high school.

It is my experience that five periods per week for one year will suffice to cover the ground indicated in *General Science* and most of the ground indicated in the *Laboratory Manual.* If there is not time to make all the experiments, Experiments 8 and 14 and others of similar detail may be omitted.

It is hoped that the heterogeneous nature of the experiments will offer something of interest and help to every pupil, and, in addition, will induce some few to take up a study of theoretical science, whether in physics or chemistry.

The metric and English systems of measurement are used indiscriminately according to convenience. The student should keep in mind that one cubic centimeter of water weighs one gram; and that an ordinary test tube

(6 inches by $\frac{3}{4}$ of an inch) contains about thirty cubic centimeters. Where only a few centimeters of a solution are to be used the liquid can be measured easily in fine burettes, and burettes of varying size should be at the disposal of each pupil.

It is desirable that *General Science* be used in connection with the *Laboratory Manual*, since the latter is not comprehensive enough to be used alone.

I take this opportunity to acknowledge my indebtedness to the following teachers of the science department: Misses Norment, Price, and Waldie, who have aided me greatly in the *General Science* and the *Manual*.

BERTHA M. CLARK.

WILLIAM PENN HIGH SCHOOL.

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LABORATORY MANUAL

HEAT

EXPERIMENT 1. THE THERMOMETER

FILL a glass tube shaped as in Figure 1 to the point *A* with mercury, and place the bulb of the tube in a beaker of boiling water which is supported on a tripod over a Bunsen flame (Fig. 2). Hold the bulb in the water for three or four minutes, and watch the mercury carefully, noting whether it rises or falls in the tube or remains stationary. At the end of several minutes note the position of the top of the mercury and mark the position on the tube by means of an ink spot.

FIG. 1.— Making a thermometer.

FIG. 2. — Determining the upper point on a thermometer.

Remove the bulb of mercury from the boiling water, and after allowing it to cool for a few minutes, put it into a beaker of chopped ice (Fig. 3); again watch the mercury in the tube, noting whether it rises or falls. At the end of several minutes note the position of the top of the mer-

cury, and mark this position also by means of an ink spot.

These two points are called the boiling point and the freezing point of water, and the distance between them is divided into equal parts called degrees. On the Fahrenheit scale it is divided into 180 degrees, and on the Centigrade into 100 degrees. The lower point on the Fahrenheit scale is marked 32°, and on the Centigrade 0°; while the higher point on the Fahrenheit scale is marked 212°, and on the Centigrade 100°.

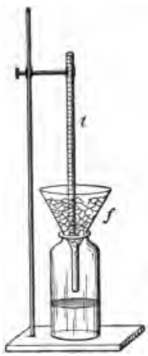


FIG. 3. — Determining the lower point on a thermometer.

A bulb of this sort filled with mercury and graduated so that unknown temperatures may be determined is called a thermometer. The Fahrenheit thermometer is used in the United States; the Centigrade is used throughout most of Europe and for all scientific purposes.

EXPERIMENT 2. TEMPERATURE CURVES

Draw two straight lines OX and OY on a piece of coördinate paper, and represent temperatures by distances above OX, and time intervals by distances to the right of OY. Let one space above OX represent one degree of temperature, and one space to the right of OY one five-minute interval. Any point on AB will represent a temperature of 12°, since it is twelve spaces above OX, and any point CD will represent a time interval of forty minutes, since it is eight spaces to the right of OY. The point at the intersection of these two lines, therefore, represents a temperature of 12°, forty minutes after

the first temperature was taken. On the assumption that the temperature rises 1° every five minutes, find the points representing ten five-minute intervals and their corresponding temperatures. With a sharp pencil draw

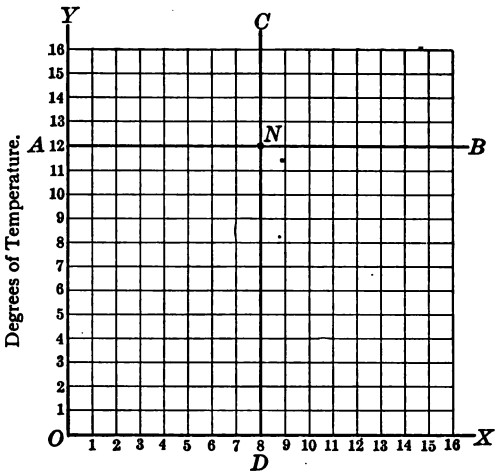


FIG. 4.—Each space above OX represents one degree of temperature; each space to the right of OY represents 5 minutes of time.

a smooth line through these plotted points. Such a line is called the temperature curve or the temperature graph.

Note and record the thermometer reading at a given place at the same time each day for a fortnight. Be careful to have the thermometer free from drafts and out of the direct sunlight.

Draw a curve which will show temperature changes for the fortnight, using distances above OX to denote temperatures, and distances to the right of OY to denote their corresponding dates.

Study Figure 5 and state which of the fourteen days was the warmest and which was the coldest.

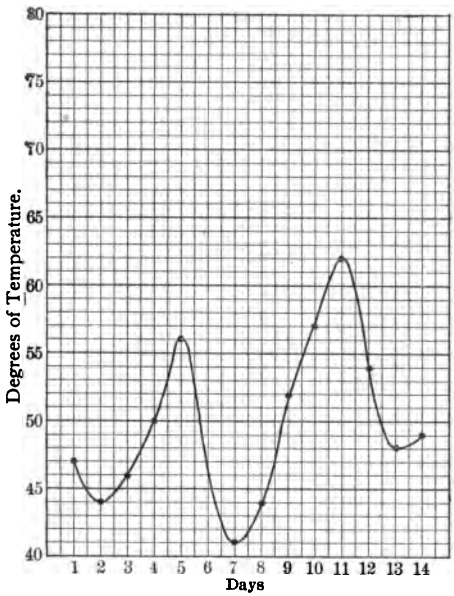


FIG. 5.—A temperature curve for a fortnight.

EXPERIMENT 3. COEFFICIENT OF EXPANSION OF A SOLID

Inclose an iron rod in a tube, allowing it to project about one eighth of an inch beyond the corks which close in the ends of the tube. Attach the tube, as shown in Figure 6, to a steam boiler containing cold water and close the opening *O* of the tube by means of a cork into which a thermometer is inserted. Note and record the reading of the thermometer. At the same time, with the aid of two

wooden blocks and a horizontal meter stick, determine as accurately as possible the length of the rod.

Apply heat to the boiler until steam passes rapidly into the tube. The steam which heats the rod must be allowed to escape through some opening, such as *E*. After the

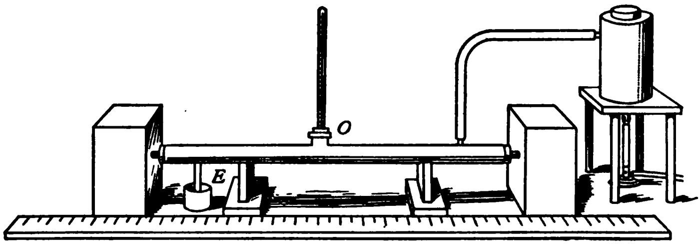


FIG. 6.—The expansion of an iron rod.

steam has been issuing five or six minutes, note the thermometer reading and measure the rod again.

What is the increase in the length of the entire rod as a result of the heating? What was the increase in temperature? Calculate the increase in the length of each centimeter of the rod. Then calculate what the increase would have been for each centimeter if the rod had been heated but 1°. This is the Coefficient of Expansion of iron, and is defined as the increase in the length of a rod 1 cm. long when heated 1°.

EXPERIMENT 4. CONVECTION OF HEAT

Set up the apparatus as shown in Figure 7.

Fill the lower vessel with colored water and the upper one with clear water. Heat the lower vessel, and the colored water will show the direction in which the current flows. Explain why the water flows as it does. Draw in your laboratory book a diagram, and show by means of arrows the direction of the current.

Explain how convection is made use of in the heating of buildings.

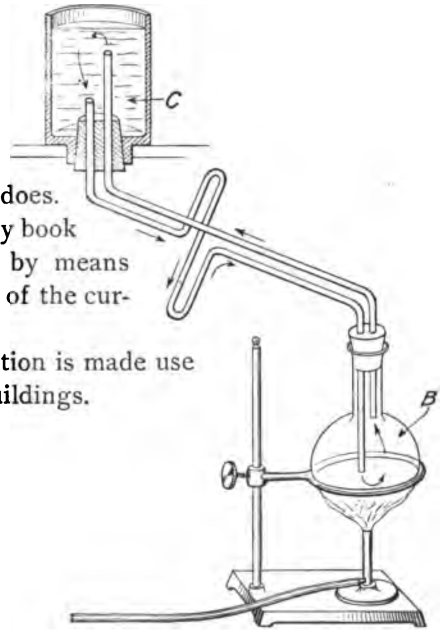


FIG. 7. — Currents caused by heat.

EXPERIMENT 5. FALL OF TEMPERATURE

(*a*) Put a convenient quantity of very hot water into a vessel provided with a close-fitting one-holed stopper through which a thermometer passes.

(*b*) Put the same quantity of equally hot water into a similar vessel covered with cotton batting or felt.

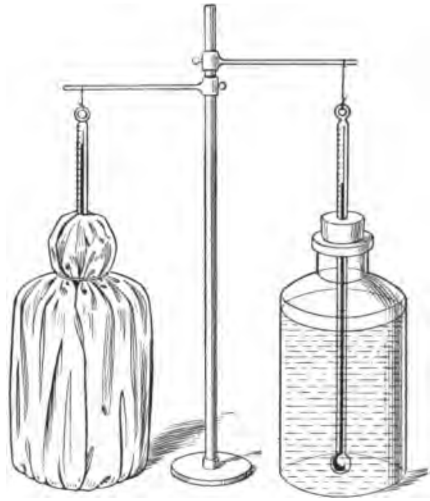
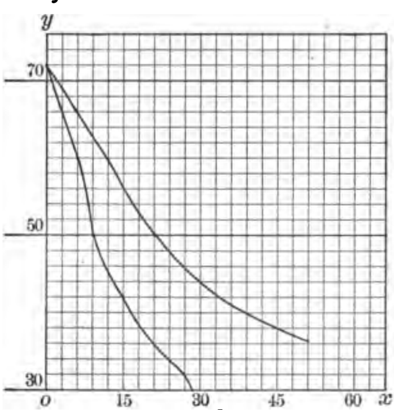


FIG. 8.— The water in the covered vessel cools more slowly than the water in the unprotected vessel.

Note and record every three minutes for half an hour the temperature of the water in the two vessels, and draw curves to indicate the changes in temperature. See Experiment 2.



1 space on oy=2°C
1 space on ox=3 Minutes of time

FIG. 9.— Temperature curves of the covered and uncovered vessels.

Explain the great difference in the two curves.

What practical application is made of the fact that the fall in temperature can be made to take place very slowly in the covered vessel?

EXPERIMENT 6. VENTILATION

(*a*) Put a short piece of candle on the table. Light the candle and allow it to burn until the flame becomes steady, then put a beaker over the candle. Is the flame extinguished at once? Why?

(*b*) Remove the beaker and relight the candle. When the flame is steady place over it a lamp chimney (Fig. 10), instead of the beaker. Although the top of the chimney is open, the flame is soon extinguished. Why?

(*c*) Remove the chimney and again light the candle. When the flame is steady replace the chimney but, instead of allowing it to rest on the table, support it on a couple of wooden blocks about one inch high. Is the candle extinguished or does it continue to burn? Why? Figure 11.

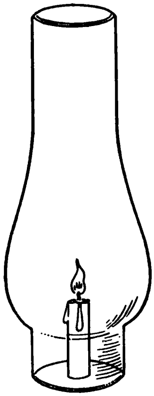


FIG. 10. — The candle does not burn well.

FIG. 11. — The candle burns brightly when the chimney is supported on blocks.

EXPERIMENT 7. LAW OF MIXTURES

When two bodies of unequal temperatures are near to each other or are touching each other, the warm body gradually loses heat and the cold body gradually gains heat until both have the same temperature. If 100 gm. of water at 40° is mixed with 100 gm. at 80, we obtain 200 gm. of water at 60° C. The warm water has lost 20° C. and the

cold water has gained 20° C.; in general, the heat gained by a cold body equals the heat lost by a warm body.

Weigh 200 gm. of hot water in a glass beaker and pour it into a vessel covered with raw cotton or wool. Then weigh 200 gm. of cold water in the same beaker. Note carefully the temperature of both hot and cold water and quickly pour the cold water into the hot water. Stir the mixture and then note its temperature.

The amount of heat gained by one gram of water when it is heated one degree, or lost by one gram of water when it is cooled one degree is called a Calorie. Compute the number of calories which your cooler water has gained. Then compute the number of calories which your warmer water has lost. Compare the amount of heat lost by the hot water and the amount gained by the cold water.

Why is the temperature of scalding water lowered so much when dishes are put into it that no cold water need be added in order to prevent the hands from burning while washing the dishes?

SPECIFIC HEAT, ETC.

When we attempt to heat equal quantities of different substances such as brass, copper, and water, we find that it requires different amounts of heat to produce the same rise in temperature. Some substances, like water, change their temperatures slowly when heated; others, like mercury and zinc, change their temperatures rapidly when heated. This difference is due to what we call the Specific Heat of the substances. The amount of heat needed by 1 gm. of a substance in order that its temperature may be increased 1° C. is called the specific heat of that substance. The specific heat may also be defined as the amount of heat given out by 1 gm. of a substance when its temperature falls 1° C.

The law of mixtures enables us to determine the specific heat of a substance. Suppose for example we wish to determine the specific heat of zinc. If 20 gm. of zinc at 90° C. is put into 60 gm. of water at 10° C., the resultant temperature is 12.41° C.; and from these facts the specific heat can be determined as follows: —

As a result of the mixture, each gram of zinc had its temperature lowered 77.59° C. If S represents the specific heat of zinc, that is, the number of calories lost by 1 gm. of the zinc when its temperature falls 1° C., then the total heat lost by 1 gm. would be S multiplied by 77.59, or $77.59 \times S$ calories. The heat lost by 20 grams of zinc would be $77.59 \times S \times 20$, or $1551.8 \times S$ calories.

The water, on the other hand, had its temperature raised 2.41° C. The amount of heat required to raise the temperature of 1 gm. of water, through 1° C., is 1 calorie. Hence 1 gm. of water in having its temperature raised through 2.41° C., must have absorbed 2.41 calories, and 60 gm. must have absorbed 2.41×60, or 144.6 calories.

Since the heat lost by the zinc equals the heat gained by the water,

$$1551.8 \times S = 144.6 \text{ calories,}$$
$$S = .093.$$

The specific heat of zinc is .093, less than one tenth the specific heat of water.

EXPERIMENT 8. DETERMINATION OF THE SPECIFIC HEAT OF LEAD

Pour into a glass beaker 200 gm. of water whose temperature is somewhat below the temperature of the room, and surround the beaker with cotton. Weigh out 100 gm. of lead shot; put it into a metal cup and set the cup in a vessel of boiling water. Allow the shot to heat for 10 or 12 minutes, stirring gently from time to time with a glass rod. Note and record the temperature of the water in the beaker and quickly pour the hot shot into it. Stir gently for 2 or 3 minutes with the thermometer and then note and record the temperature of the mixture.

Tabulate the results and calculate the number of calories of heat lost by the lead, remembering that the heat lost by the lead equals the heat gained by the water. Then calculate how many calories each gram of lead must have lost, and, finally, how many calories each gram would have lost if its temperature had been lowered only 1° C. This is the specific heat of the lead.

EXPERIMENT 9. BOILING POINTS

(*a*) Put some water into a flask and heat it over a Bunsen flame as in Figure 2. Note and record the reading of the thermometer as soon as the water begins to boil, holding the thermometer in such a way that its bulb is immediately below the surface of the liquid. The point to which the mercury rises in a boiling liquid is called the boiling point of the substance.

(*b*) Repeat, using salt water.

(*c*) Put some alcohol in a large test tube, and immerse the lower end of the tube in a large vessel of boiling water. Hold a thermometer in the test tube in such a way that the bulb is below the surface of the liquid, but does not touch the test tube. (The temperature of the tube may differ from that of the alcohol.) Note and record the reading of the thermometer when the alcohol begins to boil.

EXPERIMENT 10. MELTING POINTS

(*a*) Dip the bulb of a thermometer into melted paraffin, then quickly withdraw it and allow the adhered paraffin to harden. Insert the thermometer in a test tube and place this in a larger vessel containing water. Heat the water in the larger vessel. Note the reading of the thermometer when the first drop of paraffin falls from the bulb. Great care must be taken to keep the thermometer from touching the side of the tube.

(*b*) Find the temperature of melting ice by inserting the thermometer in a funnel of cracked ice (Fig. 3), noting readings at three-minute intervals until all the ice has melted.

EXPERIMENT 11. GLASS MOLDING

(1) *To make a stirring rod or a medicine dropper.*

Hold a glass tube, about a foot long, in the Bunsen burner (Fig. 12), and slowly rotate it in order that it may be uniformly heated. When the glass begins to soften, separate the hands, drawing out the glass into the shape shown in (Fig. 13). Then cut the tube at *c*. The cutting of glass tubes should be done as follows.

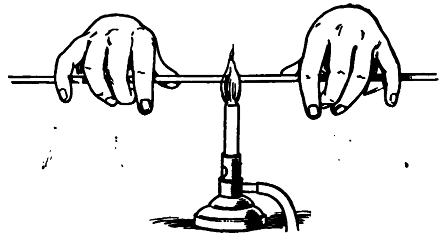


FIG. 12. — Making a stirring rod.

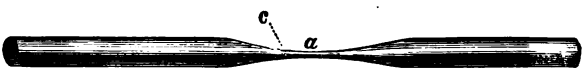


FIG. 13. — Drawing out the tube.

By means of a strong file make a short, but deep scratch on the glass where it is desired to make the cut, then grasp the tube so that the thumbs are together behind the scratch (Fig. 14), and push with the thumbs. The tube will break at the scratched point.

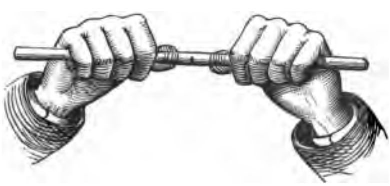


FIG. 14. — Breaking a tube.

The cutting of the glass tube leaves us with two stirrers, each of which has a sharp edge at the narrow end. These sharp edges can be rounded and smoothed off (Fig. 15) by slowly rotating the sharp end of the glass in the flame

until a yellow color appears. When the edge has been smoothed off, the tube should be slowly moved in and out of the flame to prevent sudden cooling, since any sudden heating or cooling of glass is apt to crack it. A hot tube should never be removed from a flame suddenly, nor laid on a cold surface. A cold tube should never be put into a flame suddenly, but should be moved in and out until moderately warm, when it can be held in the flame permanently without danger of cracking.

FIG. 15. — The sharp ends of the stirring rod can be smoothed off.

(2) *To make a closed tube.*

Put the end to be closed into the flame, and rotate it slowly; allow the glass to remain in the flame until it becomes molten and runs together, closing the open end.

(3) *To make a curved or bent tube.*

Hold the tube in the flame as before; but in addition to rotating it, move it slowly from right to left, so that a few inches of the rod are heated. As soon as the heated portion becomes soft, remove the tube from the flame and bend it slightly (Fig. 16); put it in the flame again, and when it has again become soft bend it further as before. Continue this until the desired curve has been made (Fig. 17).

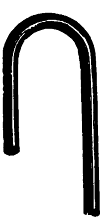


FIG. 17. — A bent tube.

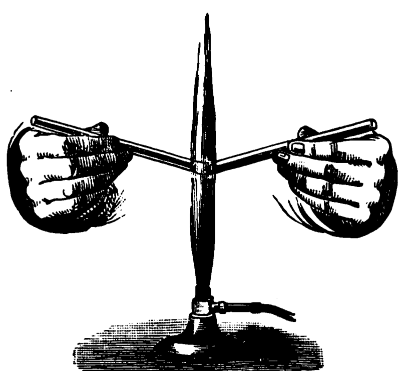


FIG. 16. — Bending glass.

Can you suggest how a bottle might be made from a closed glass tube?

Cheap dishes are made by pressing soft, plastic glass into a die. Plate glass is made by pouring molten glass on a level table, rolling it smooth with a hot metal cylinder, and polishing it after it has hardened.

Iron can be treated in a similar manner; hence the forging of iron into numerous shapes is possible.

How does the melting point of glass and of iron differ from the melting point of most substances?

EXPERIMENT 12. THE HEAT LATENT IN ICE; OR, THE ABSORPTION OF HEAT BY MELTING ICE

Weigh a glass beaker and after filling it with warm water, weigh it again. The difference between these two weights gives the weight of the water. Carefully note the temperature of the water, and then drop a lump of dry ice in the beaker. Stir the water until all the ice is melted, then read the thermometer in order to find how much the temperature of the water has been lowered by the ice. Weigh the beaker and its contents and find the number of grams of ice which have been melted in the water.

All the heat used in melting the ice has been obtained from the warm water originally in the beaker. Since the weight of the water is known, and also the change in its temperature, we can determine the number of calories of heat lost by the water in cooling. The heat thus lost by the water was absorbed by the ice; hence we can find the number of calories abscrbed by the ice in melting. Finally we can determine the number of calories absorbed by 1 gm. of ice in melting. This is called the Latent Heat of Fusion of ice.

What practical application do we make in our homes of the absorption of heat by a melting solid, or the heat of fusion?

EXPERIMENT 13. THE COOLING EFFECT OF EVAPORATION

(*a*) Allow bottles of water, alcohol, and ether to stand in a room until they have acquired the temperature of the room. Pour equal quantities of each of these liquids into three test tubes and allow the liquids to stand about three minutes. Then record the temperature of each liquid, being careful to have the bulb of the thermometer entirely below the surface of the liquids. Can you suggest why the temperature has changed in each case?

(*b*) Pour equal quantities of these liquids into three shallow dishes and after allowing them to stand about two minutes, record the temperatures of each. Are the respective temperatures of the three liquids higher or lower than in (*a*)? Why?

(*c*) Place a drop of water, alcohol, and ether on the hand, and note which disappears most rapidly. Did the drop which disappeared first seem warmer or colder than the other two? Note also which drop disappeared most slowly. Did it seem warmer or colder than the others? From your results explain the difference in the temperature changes in (*a*) and (*b*) respectively.

Why is an alcohol bath valuable in sickness?

EXPERIMENT 14. CONDENSATION

Arrange the apparatus as shown in Figure 18, having carefully weighed the water in *B* and recorded its temper-

ature. Heat the water in *A* until it boils, and allow the steam from it to pass into *B* for four or five minutes. Then record the temperature of the water in *B*, and thus determine the increase in the temperature of the water. Remove *T*; weigh the water in *B*, and calculate the number of grams which have been added to its contents by the condensation of the steam. This will give the amount of steam which has been condensed.

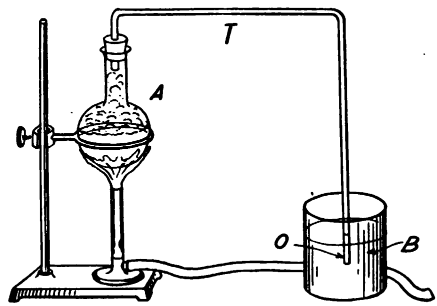


FIG. 18.—Steam from *A* condenses in *B*.

The steam lost some heat during condensation. The water formed by the condensation likewise lost heat, because its temperature was lowered from 100° to the final temperature of the water in *B*. From the law of mixtures, it follows that the total amount of heat gained by the cool water originally in *B* must equal the heat lost by the steam during condensation plus the heat lost by the warm water in cooling from 100° to the final temperature.

Calculate the number of calories gained by the cool water, and the number of calories lost by the warm water. The difference between these must be the heat lost by the steam during condensation. Since we know the amount of steam that has been condensed, we can calculate the number of calories lost by one gram of steam during condensation. This is the Latent Heat of Vaporization.

How much heat is given up by 2000 gm. of steam in

condensing? Explain how steam may be used to heat a building.

EXPERIMENT 15. SOLUTIONS

(*a*) Place a small deep beaker half full of water in a larger vessel and pack crushed ice or snow around it (Fig. 19). With a thermometer note the temperature of the water every minute until twelve or fifteen readings have been obtained.

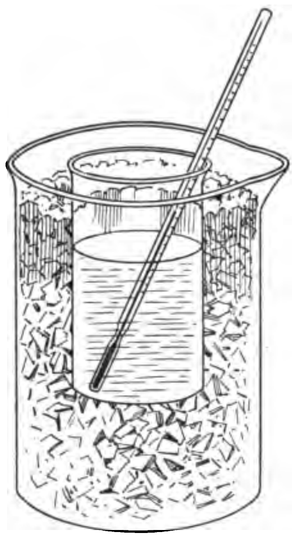


FIG. 19.—The water in the inner vessel freezes.

(*b*) Place a second beaker of water in a similar vessel and pack around it a mixture of ice and salt which consists of one part of salt and three parts of ice. Again note the temperature every minute until twelve or fifteen readings have been taken.

Does the temperature change with the same rapidity in (*a*) and (*b*)? Why?

From your results, tell why salt is put on ice in ice-cream freezers.

EXPERIMENT 16. NEED OF OXYGEN FOR COMBUSTION

Mix carefully a small quantity of potassium chlorate and an equal amount of manganese dioxide, and place the mixture in a large test tube. Close the mouth of the tube with a one-hole rubber stopper in which is fitted the delivery-

tube B, and clamp the test tube to an iron support as shown in the figure.

Fill the pneumatic trough with water until the shelf is just covered, and allow the end of the delivery tube to rest just beneath the hole in the shelf. Then fill a medium-sized bottle with water and cover it with a glass plate or heavy paper. Heat the test tube very gently, and when gas bubbles rise rapidly through the water, place the inverted bottle over the hole in the shelf and remove the plate. The gas which issues from B will rise in the bottle and force out the water. When all the water in the bottle has been dis-

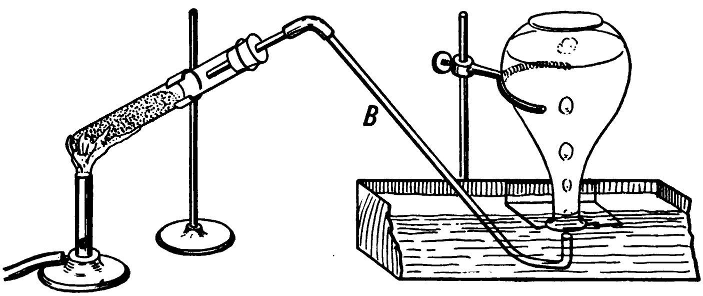


FIG. 20. — Making oxygen.

placed, slip the glass plate under the mouth of the bottle and remove the bottle from the trough. The gas which has been collected in the bottle is called Oxygen.

Dip a splinter of wood smoldering at one end into the bottle of oxygen. What happens? Remove the stick, and repeat several times. How does the glowing stick change in appearance?

Hold a piece of charcoal in a flame long enough to make it glow faintly. Then place it in a bottle of oxygen. How does it change in appearance?

From these results state your conclusion concerning the effect of oxygen on combustion.

EXPERIMENT 17. TO MAKE CARBON DIOXIDE

Put broken bits of marble into a test tube and pour over them hydrochloric acid. Collect the bubbles of gas which are formed, in a second test tube, as shown in Figure 21. What is the color of the gas? Has it an odor? Thrust a

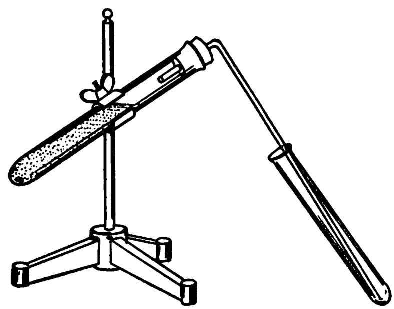


FIG. 21.— Making carbon dioxide.

burning splinter into the test tube containing the gas. Does the gas support combustion?

Mention several ways in which carbon dioxide (CO_2) and oxygen (O) differ.

EXPERIMENT 18. TESTING FOR CARBON DIOXIDE

Carbon dioxide turns limewater milky.

(*a*) Put a small quantity of limewater in an evaporating dish and let it remain uncovered on your desk during the laboratory period. Does any change occur in it? If so, explain why.

(*b*) Put some limewater in a clean beaker, and by means of a piece of clean glass tubing, blow into the limewater (Fig. 22). Does any change occur in it? If so, explain why.

(*c*) Put some limewater in a test tube and insert in the upper part of the tube a burning match or cigar. (Do not let the burning substance come into contact with the limewater.) After the match has burned for about a minute, remove it, insert a cork in the test tube, and shake the limewater. Does any change occur in it? If so, explain why.

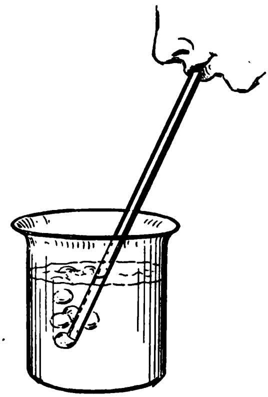


FIG. 22. — Testing the breath for carbon dioxide.

Can you suggest any way of reducing the amount of carbon dioxide in a school room?

EXPERIMENT 19. DISTILLATION OF COAL AND WOOD

(*a*) Put some small shavings of wood into a *strong* test tube and connect with a bottle as shown in Figure 23. Heat the tube gently at first and then strongly, and notice any change which takes place in the wood. While the wood is burning bring a lighted match near the exit tube *C*. What happens? How do you account for the strange result?

(*b*) Allow the tube to cool and examine what remains of the wood. What has been formed from the original wood?

The separation of a substance into simpler substances by means of heat and without a sufficient supply of oxygen is called Destructive Distillation.

Name two substances into which the wood was separated by heat.

(*c*) Fill a *strong* test tube one third full of fine soft coal and connect with the bottle as above. Heat the tube and

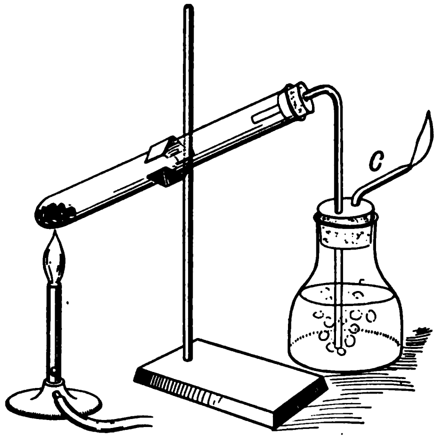


FIG. 23.— Destructive distillation.

as before test the gas escaping from the exit tube *C*. What gas is formed from the destructive distillation of soft coal? After the tube has cooled examine its contents. What remains of the coal? Name two substances into which soft coal was separated by heat.

FOODS

EXPERIMENT 20. THE PRESENCE OF STARCH IN SOME COMMON FOODS

(*a*) Put a pinch of powdered starch into a test tube and fill the test tube half full of water, shaking it thoroughly. Then add one or two drops of iodine and note whether the color of the starch-and-water mixture changes. If the application of dilute iodine to a substance produces a beautiful blue color, starch is present.

(*b*) Put a pinch of powdered starch in a tube and add water as before; then boil the mixture (Fig. 24), noting any change which occurs. If the starchy paste is too thick, thin it with hot water and shake vigorously. After the starch has cooled, add iodine as before and compare the result with (*a*).

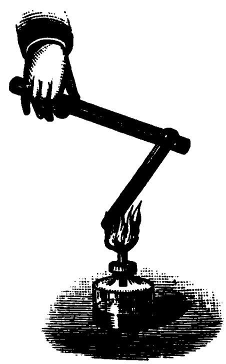


FIG. 24.— Boiling starch.

(*c*) Scrape some raw potatoes into a test tube and add sufficient water to thin the pulp considerably. Test this with iodine, and state whether starch is present in the potato.

In a similar manner test rice, oatmeal, cracker.

(*d*) Scrape some potato as in (*c*), but boil the pulp before testing it with iodine. Is there any noticeable difference between the action of iodine on raw and cooked starch?

(*e*) Scrape a bit of potato, thin it with water, and put a drop on the microscope slide. State clearly what you see under the microscope and make a rough drawing.

(*f*) In a similar manner examine a bit of cooked potato.

The starch found in uncooked vegetables, cereals, etc., is in the form of small grains which have a hard outer shell. The digestive juices of the body cannot readily penetrate this hard shell, and hence raw starch is indigestible. Heat or cooking softens the shells, swells the starch, and causes the grains to burst; hence the grains of cooked starch are in a condition in which the digestive fluids can reach them and act upon them. For this reason vegetables, fruits, cereals, and all starchy foods are more digestible when cooked than when raw.

EXPERIMENT 21. THE PRESENCE OF FATS IN SOME COMMON FOODS

(*a*) Scatter a spoonful of corn meal lightly on a thin sheet of clean paper, and lay the paper on a tin plate. Then put the plate in a drying oven for a few minutes, or if that is not possible, put it on a hot radiator. Is there any indication that the corn meal contains oil or fat?

(*b*) Shell a peanut and cut it into small bits; test as before. Is the result the same?

(*c*) Shave a piece of cheese into fine bits and place these in a test tube. Add sufficient ether to cover the cheese, then cork the tube and allow it to stand for thirty minutes. At the expiration of that time, strain the resulting solution into a shallow dish and allow the solution to stand until the ether has evaporated. What remains in the dish?

Repeat this test with white flour and graham flour. Which of these contains the more oil?

The digestive fluids of the body act on the foods which we eat very much as ether acts on cheese; they dissolve the fats and make them ready for bodily use.

EXPERIMENT 22. AN ARTIFICIAL EMULSION

(*a*) Put a teaspoonful of lard, olive oil, or butter into a test tube and add sufficient water to make the tube half full. Do the two liquids mix? Shake vigorously. Do they mix now?

(*b*) To the contents of the tube add a teaspoonful of white of egg and shake the tube thoroughly. What is the result? Such a mixture is known as an emulsion. Oil and water alone will not mix, but upon the addition of the white of egg, the oil separates into tiny drops, each of which has a thin layer of egg around it, and these droplets scatter themselves through the water and form an emulsion.

A similar process is constantly occurring within our own bodies. The fats and oils present in the foods which we eat are not soluble in water alone, but they are broken up by the intestinal fluids, and in the form of small droplets are absorbed into the body tissue. The fats required by the body are best obtained in a natural way, that is, from the oil in milk, cheese, nuts, fatty meats, etc.

Fat sometimes causes trouble in the body. For example, the fat which accompanies fried food is unwholesome because it forms a thick coating over and around the food and keeps out the digestive juices. The food is thus passed on, more or less undigested, to the intestines, which

in this way have thrust upon them more than their normal task. Partial digestion of food should take place in the stomach and other digestive organs, and completed digestion should take place in the intestines.

EXPERIMENT 23. A NATURAL EMULSION

Fats are digestible when in the form of emulsion; hence a food which contains fat in that form is easily digestible and valuable for nutrition.

(*a*) Put a drop of milk on a clean piece of glass and examine it under the microscope (Fig. 25). Notice the fat

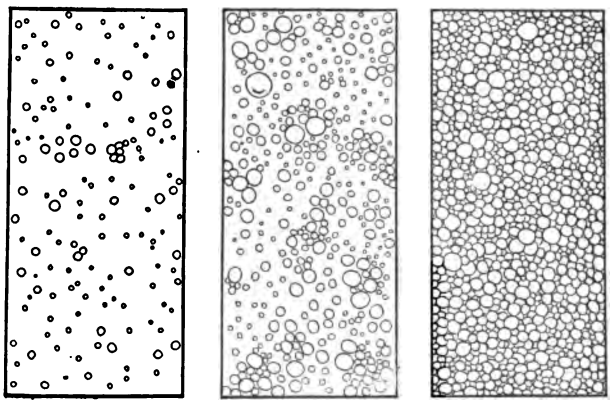


FIG. 25. — Globules of fat in skim milk, milk, and cream, as seen through the microscope.

globules and the liquid in which they float. What do you suppose the liquid is? Sketch what you see under the microscope.

(*b*) Repeat the examination for skim milk and cream. Which contains the greatest number of fat globules?

EXPERIMENT 24. PROTEIDS IN SOME COMMON FOODS

(*a*) Chop the white of a hard boiled egg into bits, put it into a test tube, and add a few drops of nitric acid. Do you observe any effect?

Rinse the contents with water and add a few drops of ammonia. What color do the bits assume? This color is characteristic of all proteids, and is unfailing proof of the presence of proteids.

Make tests for proteids in meats, onions, beans, or any other foods in which you are particularly interested.

(*b*) Mince some lean meat, pour water over it, and allow it to stand for a half hour. Draw off the watery liquid, and test it for proteids as follows. Fill a tube half full of the liquid, add a pinch of caustic soda, and shake the mixture. Then add a few drops of weak copper sulphate. If the liquid shows a violet color, proteid matter is present in it.

Judging from your experiments, would it matter materially whether meat was soaked preparatory to cooking?

(*c*) Put some meat in water and heat it until the meat boils for half an hour. Test the liquids for proteids as before. Does this give you any idea as to the nutritive value of beef tea?

EXPERIMENT 25. EFFECT OF HEAT ON PROTEIDS

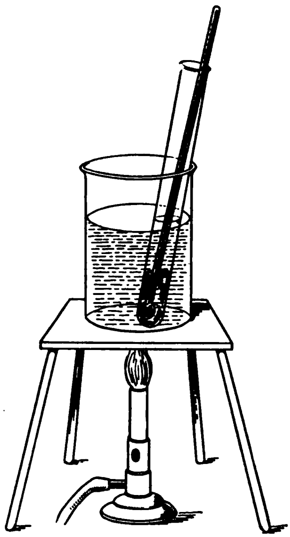


FIG. 26. — The effect of heat on white of egg.

Put the white of a fresh uncooked egg into a test tube and place the test tube in a beaker of water as shown in Figure 26. Heat the water in the beaker and notice the effect of the heating on the egg. At what temperature does the white thicken and harden or coagulate?

Can you explain why boiled milk is less digestible than cold or slightly warmed milk?

Are hard boiled eggs digestible?

EXPERIMENT 26. THE PRESENCE OF WATER IN SOME COMMON FOODS

Wash an apple and a potato until they are clean, then dry them with a cloth. Weigh each, and place them in an almost cold oven, allowing them to dry out, but not to cook. When they have dried out sufficiently, weigh them again and determine what percentage of their original weight has been lost. Make this experiment with a loaf of bread.

The loss of weight is due to the evaporation of their water content.

EXPERIMENT 27. PRECIPITATION AND FILTRATION

(*a*) In precipitation a solid and a liquid are formed from the mixing of two liquids.

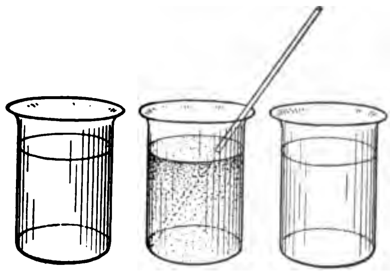


FIG. 27 — Precipitation.

Put three teaspoonfuls of lead nitrate in a test tube and then add about three times as much water.

In another test tube put about the same quantity of salt water. Now pour the two solutions into a beaker and note that a white solid has been formed from the mixing of the two liquids (Fig. 27).

The solid is called a *precipitate* and the action is called *precipitation.*

Can you suggest why it is unwise to pour medicines and unknown liquids down drain pipes?

(*b*) Fold a piece of filter paper as directed by your instructor and place it in a funnel (Fig. 28). Then pour

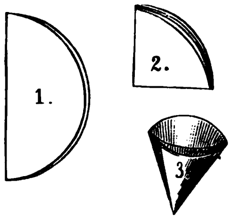


FIG. 28. — Folding filter paper for a funnel.

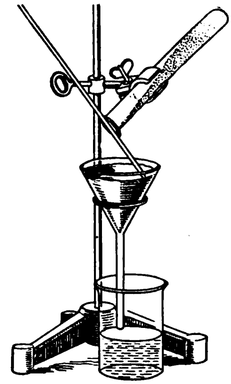


FIG. 29. — Filtration.

the contents of the beaker into the funnel, catching in a glass the liquid which runs through the funnel (Fig. 29). The solid *precipitate* stays behind. The liquid *filters* through, and the action is called *filtration*. What use is made of filtration in the home?

EXPERIMENT 28. SOLVENT ACTION OF WATER

Put some clean bright pieces of lead in a beaker containing water and allow the beaker to stand for a day or longer. Then pour off the clear water into another beaker and add a few drops of hydrochloric acid and a slight amount of hydrogen sulphide water. If the mixture of water, hydrochloric acid, and hydrogen sulphide turns black or brown, it indicates that lead is present in the water. Lead is poisonous and produces illness if it is taken into the system constantly, even in small quantities, and water containing lead in solution is very dangerous.

EXPERIMENT 29. ORGANIC MATTER IN WATER

Pour some water into an evaporating dish and put the dish on a sand bath, allowing the water to evaporate slowly. After the evaporation of the water, some solid material will probably remain in the dish. If a lighted match is applied to this residue and the material blackens, organic matter is present.

All organic matter blackens when burned slowly by a weak fire; charred wood is a good illustration.

The presence of organic matter in water is always dangerous. Decayed animal and vegetable matter, as well as small living organisms, frequently produce widespread disease, and it is principally through drinking water that many diseases, such as typhoid fever, are spread.

EXPERIMENT 30. FILTRATION

Fold a piece of filter paper so that it fits into a glass funnel. Then put some powdered bone black into the funnel and pour muddy water, or water slightly colored with red ink, upon the charcoal. Collect in a beaker the water which filters through the charcoal and the filter paper, and runs out of the funnel. Test the water for organic matter as in the preceding experiment.

Repeat this experiment, omitting the charcoal and using filter paper alone. In which case does the water contain less organic matter?

Describe the appearance of the filter paper after a pint of water has passed through it.

Give two household illustrations of filtration.

EXPERIMENT 31. DISTILLATION

Connect a flask of water, colored with a few drops of iodine or red ink, with a condenser, as shown in Figure 30. Heat the colored water until a small amount of its condensed vapor has been collected in the beaker *B*. What is the appearance of the condensed vapor? Test this condensed vapor or distilled water for organic matter as in Experiment 29. The steam from *A* passes through a narrow tube within *C*. In order that the steam may be cooled and condensed, cold water is sent through *C*, entering at *D* and escaping at *E*.

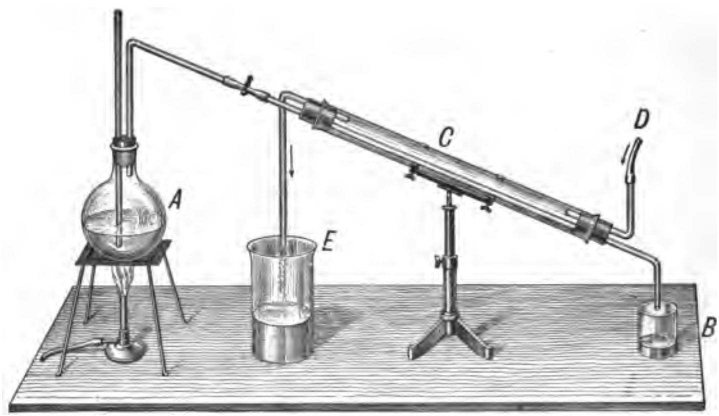


FIG. 30.—In order that the steam may be quickly condensed, cold water is sent through the tube *C*.

EXPERIMENT 32. TO TEST THE PURITY OF YOUR HOME DRINKING WATER

For this experiment the pupil must bring a pint of water from her home.

(*a*) *Test for the presence of dissolved lead.*

Into a clean test tube containing some of the sample of water, pour a few drops of hydrochloric acid and a few drops of hydrogen sulphide water and stir the mixture.

If a slightly brownish color appears, lead is present in the water in sufficient quantity to be harmful.

(*b*) *Test for the presence of sewage ; animal impurities.*

Into a clean test tube containing some of the sample of water, pour a few drops of nitric acid and a few drops of silver nitrate, and stir the mixture. If a white precipitate forms, animal impurities are present, and if a strong milkiness appears, the water is badly contaminated.

(*c*) *Test for the presence of vegetable impurities.*

Pour some distilled water into one beaker, and then into another beaker pour an equal quantity of the sample water. To each beaker add a drop of potassium permanganate (or sufficient quantity to give the water a faint pinkish tint). Then boil the specimen water for a few minutes, and afterwards allow it to cool. If the color of the cooled tested water is different from the pink tinted distilled water, vegetable impurities are present in the sample water and it is not safe for drinking.

State your conclusions regarding the quality of your home water supply.

If possible, secure a sample of spring or pond water from the suburbs and test it in a similar manner.

The above tests are crude and do not give unfailing proofs of the purity of water. Samples of water might pass these tests and still be unsafe for drinking; but on the other hand, if samples of water fail to pass these tests, the stream from which they come should not be used as a source of drinking water.

EXPERIMENT 33. TO MEASURE THE WATER AND GAS PRESSURE IN THE LABORATORY TABLES

1. Attach a U-shaped tube to the water faucet by means of rubber tubing, as shown in Figure 31, and then gently turn on the faucet. Measure the height *ac*, and the height *bc*, and by subtraction obtain the height of the column *ba*. Since the pressure of the water balances a column of mercury *ba* inches in height, the pressure of the water in pounds per square inch is one half of *ba*. (See "General Science," p. 93.)

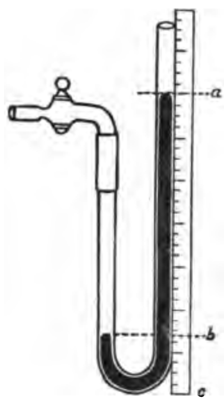


FIG. 31. — Measuring water pressure in the laboratory.

What is the pressure of the water in your laboratory faucet?

Is the water pressure in the city constant throughout the year? When is it apt to be least?

2. In a similar way calculate the *gas* pressure in your own laboratory table. Which is under greater pressure, the water or the gas?

At what time of the day would the gas pressure be least?

EXPERIMENT 34. TO FIND THE COST PER HOUR OF A SINGLE GAS BURNER IN YOUR HOME

1. Read carefully your home gas meter at some convenient time of the evening (Fig. 32). Then turn on either a single gas jet or a known number of jets, and allow them to burn for a convenient time. (Do not use a mantle burner.) It is important that you note the exact time at

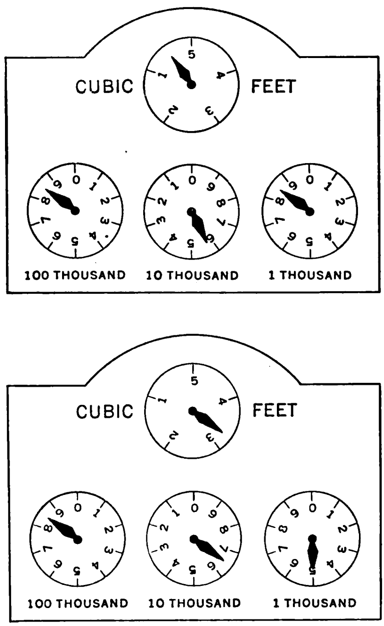


FIG. 32.— Gas meter dials.

which the jets are turned on and off; it is also important that you know just how many jets were burning during the experiment. In your laboratory notebook make two

drawings similar to Figure 32, and indicate where the dial hands stood when you took your readings.

Record as follows: —

Time of first reading.

Time of second reading.

∴ Interval during which gas burned.

Number of gas jets burned.

Length of time they burned.

Number of cubic feet of gas consumed by all the jets.

Number of cubic feet of gas which one jet would consume.

Number of cubic feet of gas one jet would consume in one hour.

2. Try the same with a mantle burner if you have one.

Which kind of burner consumes less gas, the ordinary burner or the mantle?

What is the cost of gas per 1000 cubic feet in your city?

What is the cost to you of a single gas burner per hour at that rate?

What is the cost to you of a mantle gas burner per hour at that rate?

EXPERIMENT 35. TO FIND HOW MUCH GAS YOUR HOME USES IN A WEEK OR MONTH

Read your home gas meter once a week, the same day each time, for five weeks, recording in your notebook the position of the dial hands at each reading. From these five readings find the number of cubic feet of gas used in your home in each of the four weeks; calculate the amount used in the entire time. What has been the total cost? the cost per week?

If the amount of gas consumed has varied much from week to week, can you suggest any explanation?

EXPERIMENT 36. BOYLE'S LAW

(*a*) Support in an upright position a bent glass tube, of which the short arm is closed and the long arm open, as shown in Figure 33. Pour mercury into the tube until it stands at the same level, *ab*, in the two arms. The air in the long arm is pressing upon the mercury in that arm and is tending to force it up the short arm. The air in the short closed arm is pressing down upon the mercury in that arm and tending to send it up the long arm. Since the mercury is at the same level in the two arms, the pressure in the long arm must be equal to the pressure in the short arm. But the long arm is open, and the pressure in that arm is the pressure of the atmosphere. Therefore the

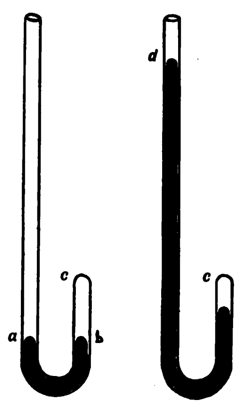


FIG. 33.— Boyle's Law.

pressure in the short arm must be one atmosphere. Measure the distance *bc* between the top of the mercury and the closed end of the tube.

(*b*) Pour more mercury into the open end of the tube, and, as the mercury rises higher and higher in the long arm, note carefully the decrease in the volume of the air in the short arm. Pour mercury into the tube until the difference in level *bd* is just equal to the barometric height, approximately thirty-two inches. The pressure of the air in the closed end now supports the pressure of one atmosphere and, in addition, a column of mercury equal to another atmosphere.

Measure carefully the distance between the mercury level in the short arm and the closed end of the tube. What effect has the doubling of the pressure had upon the volume of air in the short end?

If the tube were long enough to make the mercury column in the open end just three times as high, the pressure in the long arm would be three times that of the atmosphere. What effect would this have upon the volume of the air in the short arm?

State a law which will show the effect of pressure upon the volume of a gas. This is known as Boyle's Law.

Why will a toy balloon explode if too much air is forced into it? Why do steam boilers sometimes burst?

EXPERIMENT 37. ISOTHERMAL LINES

Make an outline map of the United States and locate the following large cities approximately : —

(1) Bangor, Me.
Montpelier, Vt.
Saginaw, Mich.
Milwaukee, Wis.
St. Paul, Minn.
Pierre, S.D.
Cheyenne, Wy.
Yellowstone Park, Wy.
Spokane Falls, Wash.

(2) Boston, Mass.
Albany, N.Y.
Buffalo, N.Y.
Detroit, Mich.
Madison, Wis.
Denver, Col.
Salt Lake City, Utah.
Boise City, Idaho.
Olympia, Wash.

(3) Annapolis, Md.
Knoxville, Tenn.
Frankfort, Ky.
St. Louis, Mo.
Topeka, Kan.
Sante Fé, N. Mex.
Phœnix, Ariz.
Santa Barbara, Cal.
San Francisco, Cal.

The cities in the first group have a mean temperature of 44°; those in the second group a mean temperature of 48°; and those in the third 58°. With a sharp pencil draw dotted lines connecting those cities which have the same mean temperature. These lines are called isotherms.

EXPERIMENT 38. BAROMETRIC CURVE

Note and record the barometer reading in the laboratory at the same time each day for two weeks. Draw a curve which will show the variation in the barometric pressure for that time, using distances above OX to denote pressures,

and distances to the right of OY to denote their corresponding dates. What is the technical expression for a curve formed in this way?

Interpretation of Isotherms and Isobars

From a map of the world, showing the isotherms, determine what regions have a mean temperature of about 50°, 60°, and 70.° What is the mean temperature of your own city?

From a map of the world showing the isobars determine what regions have approximately the same mean barometric pressure. Maps for the purpose will be furnished by the teacher.

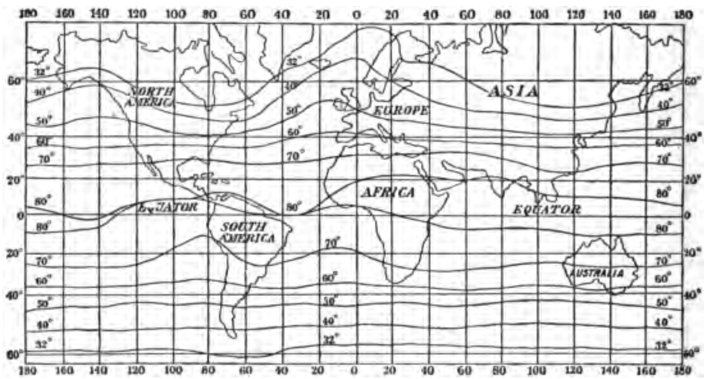


FIG. 34. — Isothermal lines.

From a local newspaper, cut out the weather chart (Fig. 35) for the day and pin it in your laboratory notebook. What meaning does this weather chart have for you? Write a brief account of the information which it contains relative to distance and local weather conditions.

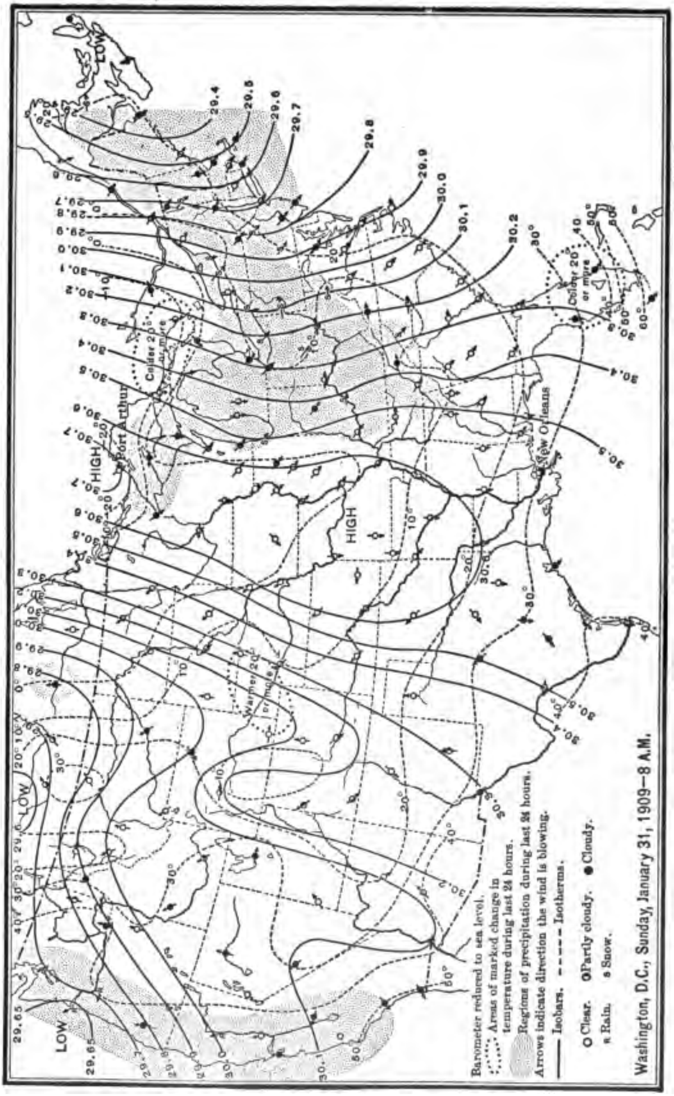


FIG. 35. — Weather chart.

EXPERIMENT 39. HEAT OF COMPRESSION

Put a small compression or bicycle pump in a beaker of water and, after taking the temperature of the water, move the piston up and down about a hundred times. Again take the temperature of the water, and from your result state whether the compression of air in the pump had a heating or cooling effect.

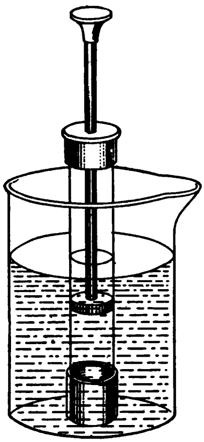


FIG. 36. — The water is heated by the pump.

A practical illustration of this is found in the bicycle pump. As the air is pumped into the tire the pump becomes hot. This is due chiefly to the compression of the air inside it. The molecules of which the air is composed are made to move more rapidly when the piston is pressed down upon them. As a result of this they strike with greater force against the sides of the pump and against each other and raise the temperature.

EXPERIMENT 40. COLD OF EXPANSION

Hold the bulb of a thermometer in front of the stopcock of a tank in which air has been compressed until it occupies only one third of its original volume. Open the stopcock and allow the air to expand, watching the thermometer carefully during the process. Does the mercury rise or fall? Has the expansion of the gas, therefore, a heating or cooling effect upon the gas?

A practical illustration of this principle is found in the refrigerating rooms on our large ocean steamers. Air is

compressed by means of engines to less than one fourth its original volume, passes through a cooler and then flows

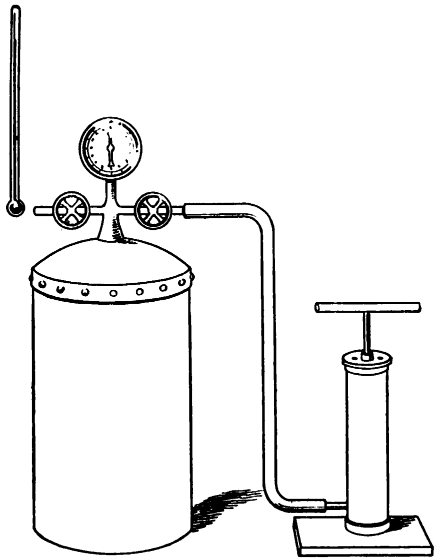


FIG. 37.—As air expands, its temperature falls.

into the refrigerating room, where its expansion produces a fall of many degrees in temperature.

EXPERIMENT 41. RELATIVE VALUE OF DIFFERENT LIGHTS

I. Set up a screen so that it will be perpendicular to a line *AB* as shown in Figure 38. At the point *O*, a slight distance from the screen, place a rod or some other opaque object in an upright position. Put a lighted candle at some point *C*, slightly at the left of *O*, but farther from the screen. This light will cast a shadow of *O* upon the screen. Place four similar candles at some point *D* to the right of *O* and farther from the screen. These will cast a second image of *O* upon the screen. If the two sources of light are moved back and forth, the two shadows will grow darker and lighter in shade. Move *C* and *D* until the two shadows are side by side and of exactly the same shade. When the shadows formed on the screen are of the same degree of brightness, the illuminations which cause them must be of equal strength. Measure carefully the distance of the two shadows from the illuminations which cause them, and compare these distances.

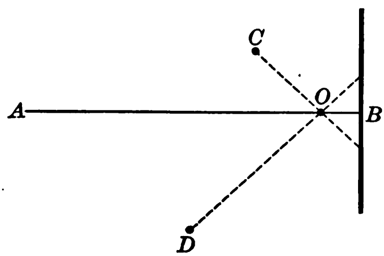


FIG. 38.—Comparing the illuminating power of different lights.

When four candles are at *D* and one candle is at *C*, how much farther from the screen must *D* be than *C*, if the shadows formed are of equal brightness?

If nine candles are used instead of four, where must *D* be placed to produce the same illumination as one candle at *C*?

State the law regarding the intensity of light at any distance from the source.

II. Using the same object, cast shadows upon the screen by means of a candle and an incandescent electric light.

As before, adjust the candle and the electric light until the two shadows are side by side and of the same brightness. The light coming from the two sources must be then equal in intensity. Measure carefully the distance of the illuminations from the corresponding shadows and compare these distances.

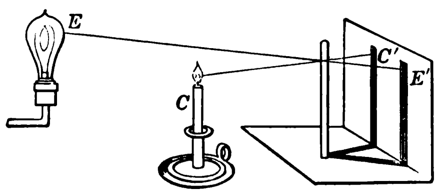


FIG. 39. — Comparing lights.

From the rule determined in I, calculate the number of candles that would produce upon the screen an illumination equivalent to that of an electric light at the same distance. This is called the candle power of the electric light.

EXPERIMENT 42. REFLECTION — HOW LIGHT IS REFLECTED

Fasten a sheet of paper to the table with thumb tacks, and with a sharp pencil draw a line *AB* near the top of the paper. Attach a mirror, or a piece of glass blackened on one surface, to a block of wood and place this block on the paper so that one edge of the mirror is coincident with the line *AB*.

At the point M, one or two inches in front of the mirror, fix a pin vertically, and at the point N, two or three inches to the right of M, fix a second pin. Images of these pins can be seen reflected in the mirror or in the blackened glass which serves as a mirror. Move the head until the image of the pin at M seems to lie directly behind the pin at the point N. Then fix another pin directly in front of N at some point P, so that the image of the pin at M, the pin at N, and the pin at P all appear to be in the same straight line.

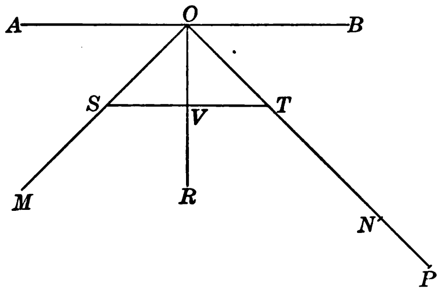


FIG. 40. — Reflection of light.

Remove the mirror and pins and join N and P by a straight line, and prolong this line until it intersects AB at O. Join M and O and erect a perpendicular OR at the point O. MO is the incident ray, and the angle of incidence is the angle between MO and the perpendicular OR, erected at the point where the incident ray meets the mirror. PO is the reflected ray, and the angle of reflection is the angle between PO and the perpendicular erected as before.

Measure off equal distances OS and OT on OM and OP, respectively, and draw ST cutting OR at V. Measure SV and TV very carefully. If they are equal, the angle SOV equals the angle TOV, because by geometry if $OS = OT$ and $SV = VT$ and OV is common, the angle SOV is equal to the angle TOV. State the laws showing the relation between the angle of incidence and the angle of reflection.

EXPERIMENT 43. THE PATH OF LIGHT THROUGH PLATE GLASS

Fasten a sheet of paper to a table with thumb tacks and at the center of the sheet, place a piece of plate glass so that it is perpendicular to the paper. With a sharp pencil, trace on the paper the outline of the glass.

On the far side of the glass stick two pins upright at the points *A* and *B*, as shown in the diagram. With the eye on a level with the table, look through the glass and move the head from side to side until one pin appears to lie directly behind the other. Then stick two more pins into the paper on the near side of the glass, in such a position that all four pins seem to lie in the same straight line.

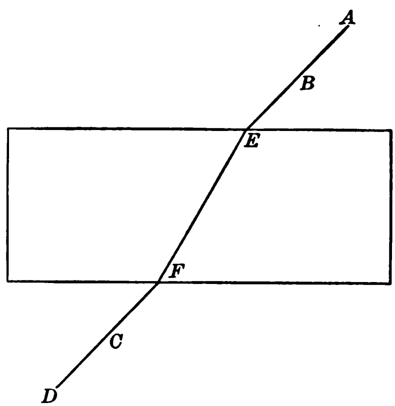


FIG. 41. — Refraction through plate glass.

Remove the piece of plate glass and the pins, draw *AB* and *CD*, and prolong these lines until they meet the outline of the glass at the points *E* and *F*. Join *E* and *F* with a straight line to show the path of the light as it passed through the glass.

From your result, state what happens (*a*) when a ray of light passes from air into a piece of plate glass; (*b*) when a ray of light passes from a piece of glass into the air. Does the emergent ray differ in direction from the incident ray? State the law of refraction.

EXPERIMENT 44. THE PATH OF LIGHT THROUGH A GLASS PRISM

Fasten a sheet of paper to the table as before, and place a prism on the paper in such a way that one face is parallel to the edge of the paper farthest away from you. With a sharp pencil trace the outline of the prism.

Then, near the edge of the paper farthest away, stick two pins upright at the points *A* and *B*, as shown in the diagram. Put two pins in front of the prism at *C* and *D*, in such a way that when you look through the prism, all four pins seem to be in the same straight line.

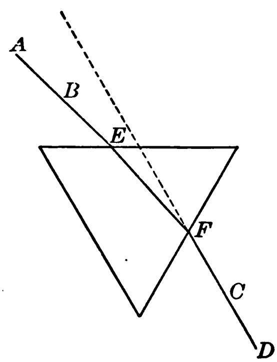


FIG. 42. — Refraction through a chandelier prism.

Remove the prism and the pins and draw *AB* and *CD* as before, prolonging them until they meet the outline of the prism at *E* and *F*. Join *E* and *F* with a straight line which will as before show the path of the light as it passed through the glass.

From your result, state what happens when a ray of light passes through a glass prism. Does the emergent ray differ in direction from the incident ray?

State the law of refraction.

EXPERIMENT 45. APPARENT DEPTH OF A POND

A pond appears to be more shallow than it is, and a basin filled with water does not seem so deep as when empty. If we put a spoon or straw in a tumbler of

water, the spoon or straw looks as though it were bent at the point where it enters the water. If we put a coin in an empty basin and move the basin so that the rim just hides the coin from view, and then fill the basin with water, the coin can be seen again. These results are due to the fact that rays of light coming from the water are bent in such a way that they seem to come from points nearer the surface. This bending of the rays of light when they pass from one medium to another, is called Refraction.

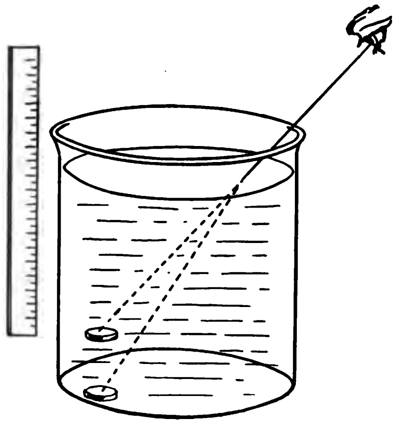


FIG. 43. — The coin looks nearer the top than it really is.

Put a coin in the bottom of a high beaker containing water, and holding a ruler against the side of the beaker, adjust the ruler until its lower end seems to be at the same level as the coin. Then measure the distance from the end of the ruler to the surface of the water; this distance is the apparent depth of the coin below the surface. Measure the distance between the real position of the coin and the surface of the water. This distance is the real depth of the coin below the surface.

How does the apparent depth of the coin compare with the real depth?

EXPERIMENT 46. PHOTOGRAPHIC PAPER

To prepare a photographic film of blue print paper: To about 24 cu. cm. of water in a small beaker add 4 gm. of ammonium citrate of iron. In another beaker dissolve 4 gm. of potassium ferricyanide, and then in a dark room thoroughly mix the contents of the two beakers in a clean shallow dish.

Lay on a table a piece of common glazed paper and give the paper a coating of the mixture, applying the liquid by means of a bit of absorbent cotton. Hang up the paper to dry, taking care that no light falls upon it.

When the paper is thoroughly dry, lay a magnet or other convenient object upon it and place the paper and the object in the direct sunlight for a few minutes. Remove the magnet and wash the paper in hot water; a clear sharp negative of the object will appear on the paper.

An ordinary negative on a glass plate can be substituted for the opaque object and in that case the blue printing paper will show a positive.

EXPERIMENT 47. LENSES

To find the focal length of a convex lens.

I. Place a convex lens in front of a distant object, as a church steeple or the chimney of a house, in such a way that it will cast an image of the object upon a sheet of paper. Move the paper until the image on it is distinctly outlined, and carefully measure the distance from the paper to the lens. The rays coming from a distant object are practically parallel, but after refraction through the lens

they converge to a point called the focus of the lens, and there form a distinct image. The distance of the lens from the focus or the point where the most distinct image is formed is called the focal length.

II. Place a candle on one side of a convex lens and a sheet of paper on the other. Adjust the candle and the paper until a distinct image larger than the object appears (Fig. 44). Measure the distance between the candle and the center of the lens and call the distance *u*. Measure the distance between the image and the center of the lens and call this distance *v*.

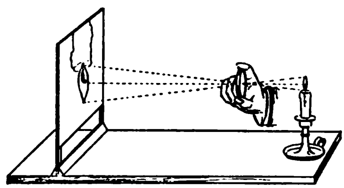


FIG. 44. — By means of a lens an enlarged image is obtained.

III. Change the position of the candle and the paper and adjust them until a distinct image smaller than the object appears on the paper. Again determine the distances *u* and *v*.

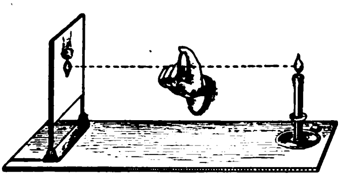


FIG. 45. — The lens is placed in such a position that the image is about the same size as the object.

IV. Change the positions of the candle and paper again and adjust both until a distinct image exactly the size of the object appears upon the paper. (See Fig. 45.) Determine *u* and *v* as before.

In I, II, III, and IV different values were determined of *u* and *v*, and it is found that as *u* changes, *v* also changes, although the focal length of the lens remains the same. There must be some definite relation existing between *u*, *v*, and *f*. Experiment shows that there is

a simple and fixed relation between *u*, *v*, and *f*, and that this relation is expressed by the formula $\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$.

With the values of *u* and *v* determined in II, III, and IV, calculate *f* in each case and compare the results with the focal length determined in I.

EXPERIMENT 48. THE MAGNIFYING POWER OF A SIMPLE LENS

Place a sheet of coördinate paper on the table and adjust the head until the eyes are about 10 inches above the paper. Keeping the head in this position, put a simple lens in the form of a linen tester in front of one eye and as close to it as possible. Keeping both eyes open, look carefully at the coördinate paper; count the number of squares in one row which can be seen through the hole. Then place the linen tester on the paper and count the number of squares in one row which can be seen through the hole without the lens. Divide the number seen with the lens by the number seen without the lens. Since this shows how many times larger a row would appear when viewed through the lens than when viewed with the eye alone, it is called the magnifying power of the lens.

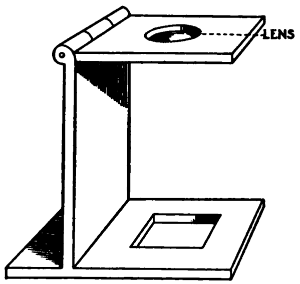


FIG. 46.—To find the strength of a lens.

EXPERIMENT 49. A TEST FOR SIGHT

The following is a very superficial test for vision.

(*a*) The normal eye is able to read type of the size shown in Figure 47 at a distance of 16 feet. By means of the printed letters (Fig. 47) examine your own eyes and determine if they are normal.

Y F E V

FIG. 47. — Crude test for nearsightedness and farsightedness.

What is nearsightedness? What is farsightedness? Explain how each can be remedied by the use of glasses.

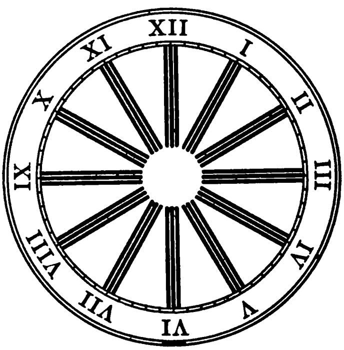


FIG. 48. — Test for astigmatism.

(*b*) Test your eyes for astigmatism by means of a card having lines of the same brilliancy radiating from the center. Astigmatism is present if some of the lines are brighter and more distinct than others.

EXPERIMENT 50. LIGHT AND ITS EFFECT ON MICRO-ORGANISMS

To ten teaspoonfuls of water add one spoonful of molasses, mixing the liquids thoroughly. Rub a little compressed yeast in a small amount of water, and put a few drops of this into the molasses water mixture.

Divide the solution of water-molasses-yeast into two

approximately equal parts and put the equal portions into clean test tubes of the same shape and size. Set one tube in a bright light and one in a dark place, but keep both tubes at the same temperature. Determine by observation whether light has any effect on the growth of the yeast plant in the mixture, and write a short description of each tube at the expiration of ten or twenty-four hours.

If a dark place is not available, wrap the tube in heavy black paper or cloth.

Does sunlight aid or inhibit bacterial growth?

Write a short account of the relation of sunlight to bacterial diseases.

Name five bacteria which are harmful to man.

Name five bacteria which are useful to man.

EXPERIMENT 51. THE CHEMICAL ACTION OF LIGHT

(*a*) Dissolve a crystal of potassium bromide in a test tube about one third full of water and then add an equal quantity of silver nitrate solution. On shaking the test tube, a precipitate of silver bromide is formed. Describe this precipitate in your notebook.

(*b*) Filter this precipitate in the usual manner, and then expose the moist filter paper to the sunlight. Describe the change which occurs, and tell what caused the change. How is this property of silver bromide utilized?

EXPERIMENT 52. ILLUMINATION AND COLOR

Soak some sheets of asbestos for several hours in a saturated salt solution. Remove the sheets and after allow-

ing them to dry thoroughly, fasten them to a Bunsen burner as shown in the figure, and light the gas. The flame will glow with a dull yellow light, due to the slow burning of the salt present in the asbestos. Lower the shades in order to exclude from the room all illumination except that of the burning salt, and record in your notebook the apparent color of ten different objects in the room. State also the true color of these objects; that is, their color in daylight.

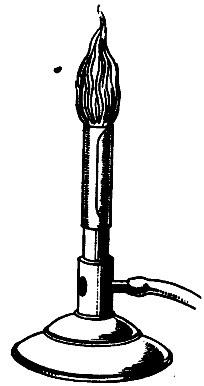


FIG. 49. — Asbestos soaked in salt will give a yellow flame.

What can you say of the complexion of your neighbor when seen in yellow light? Can you suggest any reason for this change in appearance?

Note. — A saturated solution of salt and water is one in which no more salt can be dissolved.

EXPERIMENT 53. HOW STRANGE COLORS ARE PRODUCED

To find what common colors are blended to produce the tints of old rose, London smoke, sage and mauve: —

The color top (Fig. 50) has a central peg on which colored paper disks can be slipped, each disk having a hole in the center and a slit from the center to rim. Two or more of these disks can be interlocked so as to expose sectors of various sizes and colors, and when the top is spun, the various colors of the sectors are so blended that a totally different color results.

Arrange various sectors on the top until the color

given by the spinning top matches the yarn labeled old rose.

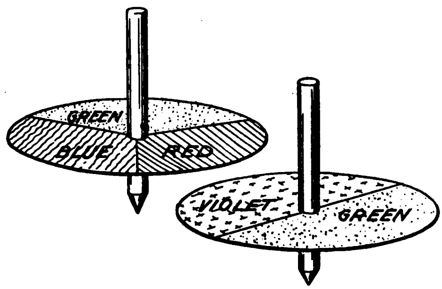


FIG. 50 — Combining colors.

In your notebook state carefully the color and size of the various sectors used in the formation of old rose.

Repeat a similar experiment for one other of the colors mentioned above.

EXPERIMENT 54. HEATING POWER OF DIFFERENT COLORS

Cover one hand with a piece of white cloth, and the other hand with a piece of black cloth, and hold both hands in the bright sunshine. Do the two hands feel equally warm? If not, account for the difference.

MACHINES

EXPERIMENT 55. THE LEVER

BALANCE a foot rule with a hole at its middle point as shown in Figure 51.

Suspend from the bar at the point 12 a weight of 1 pound. The balance is disturbed. Then from the point 3 suspend such a weight as will restore equilibrium to the bar.

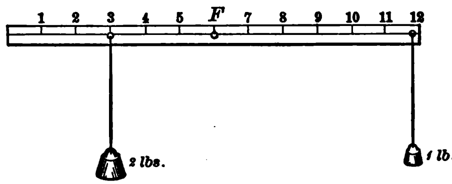


FIG. 51.— A balanced ruler.

How does the weight P suspended at the point 3 compare with the weight W suspended at the point 12?

Such an arrangement of a bar is called a lever. The point about which the bar rotates is called the fulcrum. The distance from the fulcrum to the force P is called the power arm, while the distance from the fulcrum to the weight W is called the weight arm.

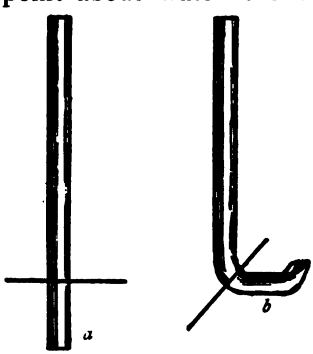


FIG. 52. — A curved lever.

In this case what is the numerical value of the force arm, and of the power arm? Under what circumstances will a small weight suffice to balance a large force?

Is it true that $P \times$ force arm equals $W \times$ weight arm?

What are some of the uses of the lever?

Levers are not necessarily straight. Suppose Figure 52 *a* represents an ordinary lever with its fulcrum at the place indicated by the dash. If now the shorter end is curved as in Figure 52 *b*, we still have a lever. Such a lever is represented by an ordinary claw hammer (Fig. 53).

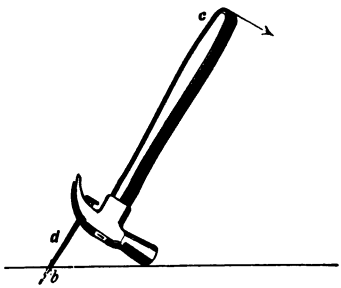


FIG. 53. — Claw hammer as a lever.

In the claw hammer a force applied by the hand at *c* removes the nail at *d*. But in order to draw the nail out one inch, the hand must move 4 times that distance, provided the arms of the lever are as 4 to 1; that is, provided the handle of the hammer is four times as long as the shorter curved end.

Give another illustration of a curved lever.

EXPERIMENT 56. THE INCLINED PLANE

Prop a smooth board in such a way that the height *AB* is approximately equal to $\frac{1}{4}$ the length of the board (Fig. 54).

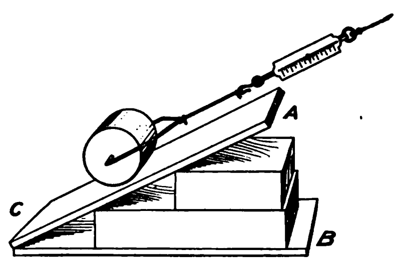


FIG. 54. — The inclined plane.

Fasten a roller (a tomato can with strings glued to it will do) to a

spring balance and draw the roller uniformly upward along the plank as shown in the figure. Note carefully the pull registered on the spring balance.

Weigh the roller, and compare its real weight with the force indicated by the spring balance as necessary to raise it along the incline.

If work equals force × distance, how many foot pounds of work would be expended in lifting the roller directly from *A* to *B*?

How much work is done in pulling the roller along the plank in an effort to raise it to *A*?

Is there any advantage in the use of the plank?

Is there any disadvantage in the use of the plank?

Is it, on the whole, advantageous or not? Illustrate.

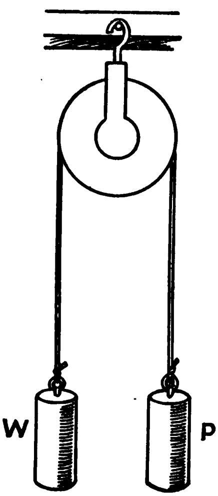


FIG. 55. — A fixed pulley.

EXPERIMENT 57. PULLEYS

A pulley is a grooved wheel around which a cord passes.

(*a*) Fasten a pulley to a support as shown in Figure 55. What weight at *P* will balance 20 pounds at *W*? Is there any advantage to be obtained from the use of this type of pulley?

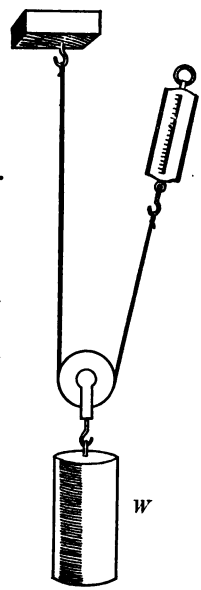


FIG. 56. — A movable pulley.

(*b*) Fasten one end of a string to a nail and the opposite end to a spring balance as shown in Figure 56.

Place a movable pulley in the string and from it hang the 20-pound weight. What pull is now registered in the spring balance? Can you suggest any reason why the pull in case (*b*) is different from that in case (*a*)?

Raise the spring balance (Fig. 56) through a vertical height of about 12 inches; the load *W* likewise moves; determine the vertical distance through which it is raised by the change in the position of the spring balance.

What is the advantage of such a pulley?

What is the disadvantage of such a pulley?

Is it, on the whole, advantageous or not? Illustrate.

EXPERIMENT 58. THE POWER OF STEAM

For this experiment the pupil should provide herself with a toy pin wheel made at home (Fig. 57).

(*a*) Heat a pint or a quart of water in an open vessel, and

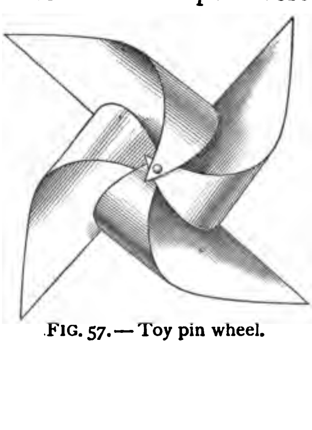


FIG. 57.— Toy pin wheel.

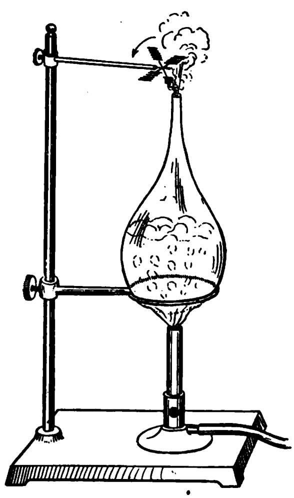


FIG. 58.— Steam as a source of power.

when the water boils briskly, hold the pin wheel in the steam. Does the pin wheel rotate?

(*b*) Heat the same quantity of water in a narrow neck flask and when the water boils briskly, hold the pin wheel in the steam. Does the pin wheel rotate (Fig. 58)?

Can you mention any practical machine in which steam is used to produce motion?

CHEMISTRY

EXPERIMENT 59. THE CHARACTERISTICS OF ACIDS

(*a*) To a few drops of sulphuric acid add a tablespoonful of water. Dip a clean stirring rod into the solution, touch the wet end of the stirring rod lightly to the tongue, and determine the taste of the acid.

(*b*) By means of the rod, put a drop of the acid on a small piece of blue litmus paper. What is the result?

(*c*) Repeat (*a*) and (*b*) for nitric acid, vinegar, buttermilk. Lay a piece of fat on the blue litmus paper and see whether the color of the paper is affected. Dissolve some cream of tartar in warm water and test for acid properties.

What are the characteristics of acids, and how could you detect the presence of an acid in an unknown substance?

EXPERIMENT 60. THE CHARACTERISTICS OF BASES

(*a*) Dissolve a small bit of caustic soda (sodium hydroxide) or caustic potash (potassium hydroxide) in a few spoonfuls of water and rub a drop of the solution between the fingers. How does the solution feel?

(*b*) Dilute still more, and then determine the taste as in the preceding experiment.

(*c*) By means of a rod, put a drop of the solution on a small piece of blue litmus paper. What is the result?

(*d*) Put a drop on red litmus paper. What is the result?

(*e*) Repeat (*a*), (*b*), (*c*), and (*d*) for limewater and liquid ammonia.

Dissolve some baking soda in warm water and test. Is it an acid or a base?

What are the characteristics of bases, and how could you detect the presence of a base in an unknown substance?

A solution which turns blue litmus red is said to have an acid reaction; a solution which turns red litmus blue is said to have an alkaline (basic) reaction.

EXPERIMENT 61. NEUTRALIZATION

To a solution of caustic soda, add very slowly and gradually small quantities of hydrochloric acid, testing the resulting solution from time to time with fresh pieces of red litmus paper. Add acid until the red litmus paper is not affected by the acid-base solution.

When this point is reached, test the solution as to taste and feeling. Is there any well known substance which it tastes like?

If an acid and base are mixed in the proper proportions, the result is a solution which has neither an acid nor a bitter taste, nor a slimy feeling. The new substance has none of the properties of either of its components, and the acid and base are said to have neutralized each other.

EXPERIMENT 62. TO MAKE SOAP

(*a*) Put a pinch of caustic soda in a small beaker of water and add about a teaspoonful of lard or olive oil. Allow this to boil for almost half an hour and then set aside to cool. When cool, mix a little of the solution with hot water and see whether it forms a lather.

(*b*) Put soda and lard in a beaker as in (*a*), and let it boil for half an hour as before. Then add slowly four teaspoonfuls of common salt, stirring constantly until the salt is dissolved. Set the vessel aside to cool, and when convenient, remove the solid cake which floats on top. Mix some of the solid with water and see whether it forms a lather.

(*c*) Make a lather of the soap with distilled water, and test with litmus paper to see whether it is neutral or whether it contains an excess of acid or base.

(*a*) In similar manner test the specimen of school soap furnished by your teacher. Bring from home a few shavings of the laundry soap used by your mother. Is it pure and fit for fine work?

EXPERIMENT 63. HARD WATER — SOAP

In order to obtain a specimen of genuine hard water, put a pinch of plaster of Paris, calcium sulphate, into a test tube of clear cold water. Shake the test tube thoroughly, then filter the contents. The filtrate will be hard water.

(*a*) To hard water in a test tube add a drop or two of liquid soap, and shake the mixture. Do suds form? Does a precipitate form; if so, what is the cause of the precipitate? Why is hard water not suitable for laundry and bath?

(*b*) To another specimen of hard water add a small

quantity of washing soda, and shake the tube. Then add a drop or two of liquid soap to this mixture. Do suds form? Does a precipitate form? What effect has washing soda on hard water?

EXPERIMENT 64. BAKING SODA

(*a*) Mix a little baking soda with some vinegar and describe what occurs. Taste the mixture and describe it by a single word.

(*b*) Repeat (*a*) for buttermilk and sour milk.

(*c*) Dissolve some cream of tartar in warm water, and then by means of litmus paper determine whether it is an acid or an alkali. Dissolve some baking soda in warm water and mix it with the cream of tartar solution. Describe the result.

Mix dry cream of tartar and baking soda, and describe the result. Pour hot water on the dry mixture and state what happens.

What is a mixture of dry baking soda and cream of tartar called?

Why should soda not be used alone in baking?

Why should it always be used in connection with an acid?

EXPERIMENT 65. BAKING SODA

Put some baking soda into a test tube and heat it over a Bunsen flame. Let the gas which is formed bubble into the limewater as in Figure 21. What is the effect on the limewater? What do you think the gas is?

After the baking soda has been heated for some time, allow it to cool. Does it look different after the heating?

Put a pinch of the heated soda into hard water and see whether it softens the water. Has the heat changed the character of the baking soda? What do we call baking soda after it has been strongly heated and changed in character?

EXPERIMENT 66. BLEACHING POWDERS

For this experiment, the pupil should bring from home pieces of colored gingham or calico, flannel and silk; also small pieces of unbleached muslin.

(*a*) Put a teaspoonful of bleaching powder in a tumbler of cold water, and after a fair amount of it has dissolved, filter off the clear solution. Dip a piece of colored gingham in the filtered bleaching solution, remove it, and state whether or not its color has been affected.

(*b*) Add a small amount of vinegar to the bleaching solution, and then quickly dip into the tumbler a fresh piece of gingham. What occurs?

Is the result the same in (*a*) as in (*b*)? Can you suggest any reason for the change? Why must the cloth be immersed in the bleaching solution as soon as the vinegar has been added?

(*c*) Into a bleaching solution to which acid has been added, as in (*b*), dip a piece of flannel or silk. What is the result?

Repeat (*a*), (*b*), for unbleached muslin.

EXPERIMENT 67. THE REMOVAL OF STAINS

For this experiment the pupil should bring from home samples of white and colored cloth, and a piece of black silk.

(*a*) Drop some ink on a piece of white cloth and try to remove it by washing in milk. Do the same for colored cloth.

(*b*) Take fresh samples of the two kinds of cloth, and drop ink on them as before, this time removing the stain by a bleaching powder solution.

Which method is preferable, (*a*) or (*b*)?

(*c*) Rub a greasy rag over one of your colored samples, and then try to remove the stain by washing the cloth in hot water. If this is not effective, try soap and water.

(*d*) Rub a greasy rag over one of your colored samples, but this time remove the grease stain with benzine. Which method of removing stains is preferable? When could one method be used and not the other?

(*e*) Put a drop of paint on a sample of cloth. Try to remove it (1) with hot water, (2) with bleaching solution, (3) with benzine, (4) with turpentine.

Which is preferable?

(*f*) Drop vinegar or lemon juice on a sample of black silk. What happens? Apply weak ammonia to the spot, and state the result.

(*g*) Rub a rusty nail on one of your samples until an iron rust stain appears. Then moisten the stain with lemon juice and finally rub common salt over the discolored spot.

If lemon juice is not available, the cloth can be dipped in dilute hydrochloric acid, then rinsed in weak ammonia, and finally washed in clear water.

EXPERIMENT 68. DIRECT DYEING

Put two grains of picric acid into 200 gm. of water and mix thoroughly. Put equal amounts of the mixture into

two shallow dishes and heat each for a few minutes. Into one of the dishes put a piece of woolen material, and into the other dish put a piece of cotton material. Let the liquids come to a boil and then remove the material. Rinse the woolen and cotton strips thoroughly in water and state what effect the dye had on each. Can you suggest any reason why one kind of material might dye better than another kind?

EXPERIMENT 69. INDIRECT DYEING. MORDANTING

(*a*) Mix ten drops of alizarin coloring matter with 200 c.c. of water and divide into three portions. Heat one portion and put into it specimens of woolen and cotton material. After the liquid has come to a steady boil, remove the materials to be dyed, and rinse them in water. State what effect the coloring matter had on each kind of material.

(*b*) Dissolve 4 gm. of iron acetate in about 200 c.c. of water. In another dish mix 10 c.c. of ammonia with 100 c.c. of water.

Dip the woolen cloth first into the iron acetate solution, then into the ammonia solution. After it has been thoroughly soaked in these two solutions, boil it in the alizarin solution. Rinse as before and state the result.

(*c*) Repeat the process for cotton and silk. State the result.

Which process of dyeing is more satisfactory, direct or indirect dyeing?

EXPERIMENT 70. TO DETECT THE PRESENCE OF FAT AND OIL IN FOODS

(*a*) Soak some finely chopped alkanna root in alcohol for a short time. Filter off the extract and dilute it with several times the quantity of water.

(*b*) Heat a portion of the diluted extract almost to the boiling point, then allow it to cool and note the color.

(*c*) Into another test tube containing dilute alkanna extract put a few drops of olive oil. Heat the mixture, allow to cool, and note the brilliant red hue acquired by the oil globules. Any substance which contains oil will turn heated alkanna extract red.

(*d*) By means of alkanna extract test chocolate, cornmeal, and soap for oils.

(*e*) In similar manner test candy of a cheap grade; candy of the same kind but of the best grade.

If the tests show that both the cheap and the expensive candy specimens contain fatty substances, should you think that the fats were the same in the two cases?

What possible fats might be present in the best grades of confections? What fats are probably present in the cheap grades of confections?

EXPERIMENT 71. TO DETECT ARTIFICIAL COLORING MATTER IN FOODS

(*a*) Boil strips of woolen cloth first in a dilute solution of soda and then in water. By this treatment, greasy matter and foreign substances are removed from the cloth, and it is made clean.

(*b*) Dilute some commercial catchup, wine, jam, or jelly

to quarter strength or less, and filter; to the filtrate add a small quantity of hydrochloric acid.

(*c*) Boil the woolen strips for five or ten minutes in the solution made in (*b*), remove them, wash them thoroughly in warm water, and note their final color. If coal tar dyes are present, the strips will become vividly colored.

(*d*) Repeat the test, this time using home catchup, jelly, or wine. Is there any difference in the color acquired in (*c*) and (*d*) by cloth strips?

Vegetable and fruit juices usually stain wool a faint and dull color, and the pupil must not confound this natural coloration with the vivid hues of the coal tar dyes.

EXPERIMENT 72. TO DETECT ARTIFICIAL COLORING MATTER IN FOODS

(*a*) Boil a piece of white woolen cloth in a one-tenth solution of sodium hydroxide ($NaOH$), and then wash it thoroughly in water.

(*b*) Dilute 10 c.c. of the suspected food material, such as ice cream, catchup, or the sirup of canned fruits, etc., with 50 c.c. of water. To this, add 5 c.c. of a 10 per cent solution of potassium bisulphate, and boil the mixture.

(*c*) Into the liquid formed in (*b*) place the woolen cloth, and allow it to boil about ten minutes.

Remove the cloth, wash it thoroughly in boiling water, and dry it between filter paper. If the white cloth acquires a bright red color, coal tar dye is present in the food material being tested.

If the white woolen cloth does not become bright red, the pleasing color of the food is due to pure fruit, and not to coloring matter from coal tar dyes.

EXPERIMENT 73. TO DETECT ALUM IN BAKING POWDER

To about 2 gm. of flour add $\frac{1}{2}$ gm. of baking powder. Pour on this enough water to make a thin dough, and then add several drops of tincture of logwood and ammonium carbonate solution. Mix the mass thoroughly and note the color. A blue hue indicates the presence of alum.

Try this test on flour to which no baking powder has been added, and note the color.

EXPERIMENT 74. TO DETECT FORMALDEHYDE IN MILK

Put a small amount of milk in a casserole and add an equal quantity of acid reagent.* Heat slowly over a slow flame, shaking the casserole from time to time in order to prevent the curd from collecting in a lump.

Just before the boiling point is reached, remove the vessel from the fire, and note the color of the cooling liquid. If the solution turns brown, no formaldehyde is present in the milk; if, however, the solution shows a violet color, formaldehyde is present as a preservative. A faint violet coloration indicates the presence of a small quantity of this preservative; a deep coloration indicates the presence of a large amount.

EXPERIMENT 75. TO DETECT GELATIN IN MILK AND ICE CREAM

Put 30 c.c. of acid mercuric nitrate and 60 c.c. of pure water into 30 c.c. of milk or ice cream. Allow this mixture

* The acid reagent for this experiment is made by adding to 1 liter or hydrochloric acid, 2 c.c. of a 10 per cent solution of ferric chloride.

to stand for a few minutes, and then filter. If the resulting filtrate is cloudy, gelatin is present in the milk.

To the filtrate add a few drops of picric acid; if gelatin is present, it will be precipitated as a yellowish mass.

Acid mercuric nitrate is made by mixing 1 ounce of mercury with 2 ounces of nitric acid (HNO_3) and diluting 20 times with water.

EXPERIMENT 76. TO DETECT BORIC ACID AND SULPHIDES IN MEAT

(*a*) Cut a small quantity of lean meat into small pieces and place it in an evaporating dish. Over this pour some water to which a few drops of hydrochloric acid have been added, and warm the whole slightly. Into the extract thus formed dip a piece of turmeric paper, remove it, and allow it to dry. If the paper shows a rose-red color on drying, boric acid is present in the meat.

(*b*) Put some sausage meat into a dish, and add a small quantity of zinc and hydrochloric acid. If sulphides are in the meat, they will react with these chemicals and will form hydrogen sulphide. The hydrogen sulphide, if present, can be detected in the following manner: Dip a piece of filter paper, moistened with lead acetate, into the meat solution. If a black precipitate forms on it, hydrogen sulphide is present and sulphides have been used in the meat as preservatives.

EXPERIMENT 77. TO DETECT COTTONSEED OIL

Cottonseed oil is frequently substituted for olive oil and other expensive oils. Cottonseed oil is wholesome food,

but it should not pass under a false name; hence some simple means for detecting it is desirable.

Dissolve 1 gm. of sulphur in 100 c.c. of carbon disulphide and an equal volume of amyl alcohol. This solution is known technically as Halphen's reagent. In order to test for cottonseed oil, mix equal quantities of Halphen's solution and the oil under consideration in a test tube. Immerse this tube in a water bath as in Figure 26, and allow the contents to heat for about twenty minutes. If a faint red color appears, a small quantity of cottonseed oil is present; if a deep red color appears, a large quantity of cottonseed oil is present. If there is no evidence of red, the oil examined does not contain cottonseed oil.

EXPERIMENT 78. CHEMICALS AS PRESERVATIVES

Mix the white of an egg with about ten times its weight of water and put approximately equal portions of the mixture into 6 test tubes.

(*a*) To one of these test tubes add about 5 drops of carbolic acid solution; to another, 2 gm. of borax; to another, 2 drops of formalin; to another, 2 drops of corrosive sublimate; to another, a pinch of salt; and to another, a pinch of sugar.

Shake the various test tubes thoroughly in order to mix their contents, plug them with raw cotton, and set them aside in a warm place. Note from day to day the appearance of the different tubes, and state which chemicals seem to be the best preservatives. Which of the preservatives do you consider safe? Illustrate the use of these in preserving foods.

EXPERIMENT 79. THE EFFECT OF HEAT ON BACTERIA

(*a*) Put some bits of raw meat in a test tube of water, plug with raw cotton, and set aside in a warm place.

(*b*) Put an equal amount of raw meat in a test tube of water, but boil the contents for half an hour before plugging and setting aside in a warm place.

At the end of a day are the contents of the two vessels in equally good condition? At the end of two days?

(*c*) Put a small quantity of milk in a test tube, and immerse the vessel in a water bath. When the water is at or near the boiling point, remove the test tube of milk, plug it with cotton, and set it aside in a warm place. Is the milk sour at the end of a day? Try the experiment with unheated milk and compare results.

Explain how cooking assists the preservation of food.

SOUND

EXPERIMENT 80. SOUND DUE TO VIBRATION

ATTACH a thin cork 2 inches in diameter to a brass rod about 5 feet in length, and clamp the rod firmly, as shown in the diagram. By means of a cork, *C*, close one end of a glass tube about $2\frac{1}{2}$ inches in diameter and 3 feet long, and insert a little sand at the open end. Hold the tube in a horizontal position and shake gently until the sand is evenly distributed from end to end. Then slip the tube over the rod and allow it to rest on short wooden blocks,

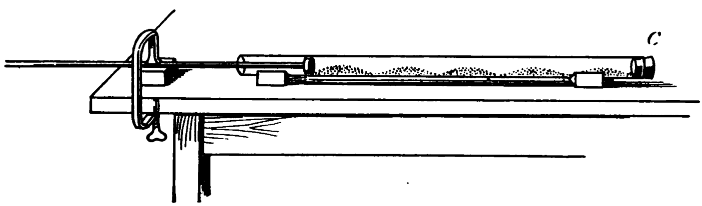


FIG. 59. — The sand is disturbed by sound.

as shown in Figure 59, being careful that the cork on the rod does not touch the sides of the tube. Grasp the extended end of the rod with a well resined cloth and stroke it longitudinally. A loud, shrill note will be heard, and at the same time the sand will be set in motion.

Since the cork does not touch the tube, and since the tube itself does not vibrate when the rod is stroked, what produces the motion of the sand? What is your conclusion,

therefore, concerning the effect of a sounding body upon the air surrounding it?

EXPERIMENT 81. THE REFLECTION OF SOUND

Place two wide glass tubes at any convenient angle, and between them insert a piece of thick cardboard, as shown in the diagram. Put a watch at the end *A* of one of the tubes, and the ear at the end of the other tube. No sound can be heard at *B*, because the sound waves which travel directly from *A* to *B* are cut off by the cardboard.

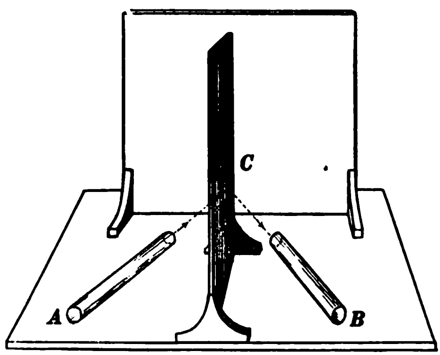


FIG. 60. — The ticks of the watch are reflected from the cardboard.

Put a second piece of cardboard in position *C*, so that it makes equal angles with the two tubes, and again place the ear at *B*. The ticks of the watch become audible. Why?

Change the position of the cardboard *C* so that it makes unequal angles with the two tubes. Is the intensity of the sound altered, or does it remain the same? Why?

EXPERIMENT 82. RESONANCE

Set up the apparatus as shown in the diagram. By raising and lowering *B* the height of the water in *A* can be changed.

Strike a tuning fork with a soft mallet or rubber hammer, and hold it over *A* so that the flat face of one prong is directly above the end of the tube. While the fork is sounding, move *B* so that the level of the water in *A* is slowly changed. As the level changes, the loudness of the sound varies, and at one level a very intense sound is heard. At certain other positions of the water in *A* there is very strong reënforcement of the sound of the tuning fork. Note very carefully one level of the water when decided reënforcement occurs.

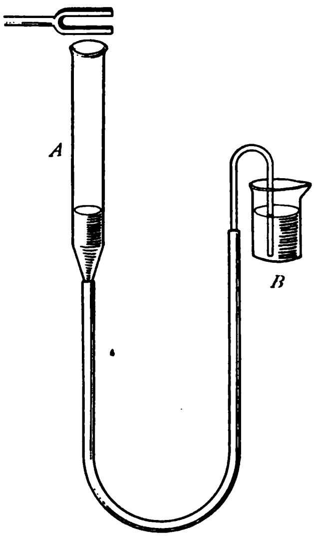


FIG. 61. — The sound of the tuning fork is strengthened by reflection from the water.

This reënforcement of sound by means of waves reflected from the water is called *resonance.*

Repeat the above, with forks of different pitch. What conclusion do you draw regarding the pitch of a note and the height of a column of air necessary to produce resonance?

EXPERIMENT 83. A TEST FOR HEARING

(*a*) Sit in a chair and have your laboratory partner hold a ticking watch at the side of one ear. Determine how far the watch can be carried from the ear before it ceases

to be audible. Test the other ear and see if it is equally acute.

(*b*) Hold a ticking watch between the teeth, and note whether the sound seems faint or loud.

Close both ears with cotton and compare the result.

(*c*) Keeping the ears closed with cotton, lay the watch against the bony part of the nose and state the result.

Can you suggest any reason why these tests are of decided value in an examination of one's hearing?

ELECTRICITY

EXPERIMENT 84. SOME EFFECTS OF ELECTRICITY

1. Put a weak solution of sulphuric acid into a beaker or tumbler, and then place in the liquid a strip of zinc and a strip of copper, being careful that the two strips do not touch each other.

Connect the wires fastened to the metal strips, as shown in Figure 62, and then examine very carefully the contents

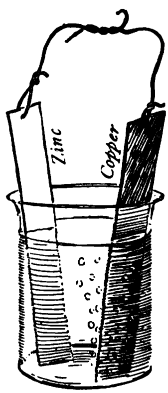


FIG. 62. — The simple cell.

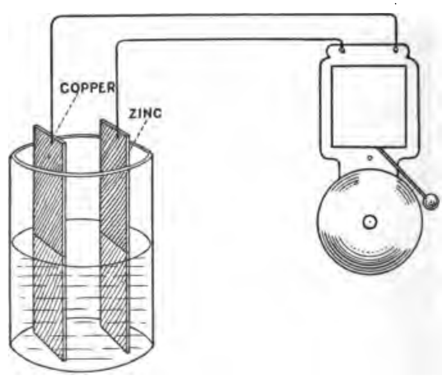


FIG. 63. — Electric current causes the bell to ring.

of the beaker. Describe any changes which you notice. Does either strip of metal seem to be strongly affected by the acid solution?

Such an arrangement of an acid and metal strips is called an electric cell.

2. Separate the wires which connect the zinc and the copper, and touch the ends to the tongue. Is there any evidence that something is passing along the wire?

Touch the tongue with the ends of wires which are not in any way connected with the cell. Do you have the same sensation as before?

3. Fasten the free ends of the connecting wires to an electric bell as shown in Figure 63. What results?

4. Connect the wires as in Figure 64. Hold a delicate compass in your hand, and notice the exact position of the needle. Then place the compass directly above or beneath the connecting wire and as close as possible to it. Is the needle affected in any way?

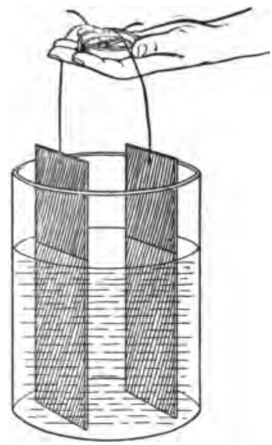


FIG. 64.— Electric current affects the compass needle.

Try this with the connecting wires slightly separated. Is the needle affected?

5. Hold a few iron filings in the palm of your hand, and let the connecting wires touch them; are they affected? Remove the hand, and state whether any filings adhere to the wire.

Try this with the connecting wires slightly separated, and state the result.

Remarks

The simple cell made by you in (1) may not be strong enough to affect the bell, the compass, and the filings.

In that case, secure a ready-made commercial cell (Fig. 65) from your instructor. These cells are manufactured and sold by all electric companies, and are stronger and more convenient than the simple cell. Although such a cell may look very different from your own arrangement, the principle is the same; within the cell chemical action takes place between an acid solution and metal strips, and produces a current of electricity.

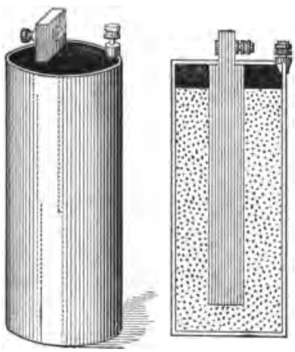


FIG. 65.— A ready-made commercial cell.

We have seen that when any separation or break occurs in the connecting wires, the electrical properties of the wire vanish. This is because current must have an unbroken path. It can pass along wire, but it does not pass easily through air, and as soon as a gap occurs in the connecting wires, the circuit path is broken, the electric circuit is not complete, and current ceases. In future experiments be sure that your electric circuit is complete. If your experiments do not work as they should, it may be because of a broken circuit.

EXPERIMENT 85. ELECTRICITY AS A SOURCE OF HEAT

Put a pint and a half of water of known temperature into a glass vessel large enough to be about half filled with this quantity. Then place in the beaker a 16 candle power electric-light-bulb. Connect the bulb with the electric light circuit in your laboratory, and allow the glowing bulb to heat the water for five or six minutes.

By means of a thermometer, determine the increase in the temperature of the water. Calculate what the temperature increase would have been if only a pint of water had been used. (Remember that the smaller the quantity of water used, the higher will be the temperature.) Calculate also what the increase of temperature would have been if the bulb had been in the pint of water for *one* minute instead of for five or six minutes.

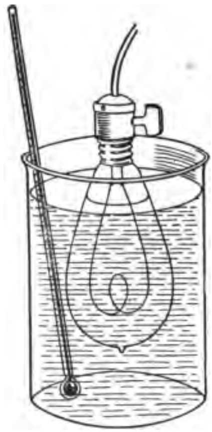


FIG. 66.—The electric bulb heats the water.

What practical use is made of the heating power of electricity?

Which would yield more heat, a 16 candle power bulb or a 20 candle power bulb?

EXPERIMENT 86. ELECTRICITY AS A MAGNET

1. Dip a nail or an iron rod into iron filings, and notice that the filings do not adhere to the nail or rod.

FIG. 67.—Coil and soft iron rod.

Wind wire around the nail, or slip the nail into the coil of wire furnished by your instructor, and notice that this too fails to attract iron filings. But connect the ends of the coiled wire with an electric cell, and then test with iron filings. What is the result?

Place some small tacks on the table and see whether you can lift them by bringing the coil near them. *Current makes a coil attract iron.*

2. Slip the nail out of the coil, connect the

coil with the same cell, and state whether more or fewer filings adhere than before.

The lifting power of a coil can be increased by sending more current through it, and by winding it closer. To try the effect of increased current, connect the coil with two or three cells instead of one.

A coil of wire having an iron core and traversed by an electric current is called an electromagnet. In factories where much metal is used, the metal shavings and clippings are often raised from the floor by electromagnets.

EXPERIMENT 87. THE ELECTRIC BELL

Connect an electric bell to a cell (represented by) as shown in Figure 68. If the bell is large and the cell is weak, the current may not be strong enough to ring the bell. In this case, use several cells, getting their combined effect by joining them as in Figure 69.

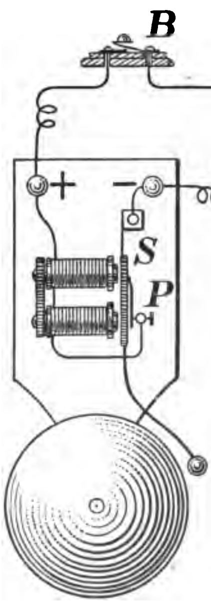


FIG. 68. — The electric bell.

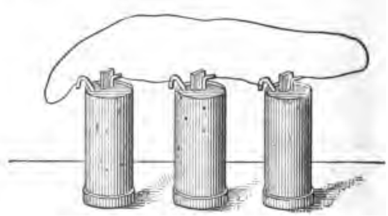


FIG. 69. — A battery of cells.

When the bell does ring, watch it very carefully for a few seconds in order to determine what part of it is in motion.

Make a careful drawing of the mechanism of the bell, and explain fully where motion occurs and why.

When your home door bell fails to ring, what do you think may be one trouble?

EXPERIMENT 88. MAGNETS AND THEIR ACTION ON IRON FILINGS

1. Lay a strong bar-shaped magnet on iron filings; then remove and sketch the appearance of the bar.

The places at which the filings adhere in greatest number are called poles. How many poles does the bar magnet have?

2. Lay the magnet on the table, put a sheet of paper over it, and lightly sprinkle iron filings on the paper. Tap the paper gently. Do the filings assume any definite arrangement? If so, sketch the appearance roughly.

Repeat the experiment, using a thin piece of glass instead of paper. Is the arrangement of the filings the same as before?

What do we call the lines along which the filings arrange themselves?

3. Lay a horseshoe-shaped magnet on filings; remove, and sketch the appearance. How many poles does this magnet have? Using the horseshoe magnet, repeat the experiment which shows the existence of lines of force, sketching the appearance as before.

EXPERIMENT 89. THE ACTION OF MAGNETS ON EACH OTHER

1. Place a delicately suspended magnetic needle on the table, and determine the direction in which it always points.

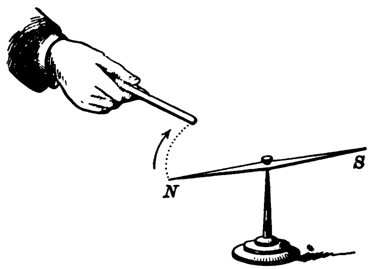


FIG. 70.—The magnet influences the magnetic needle.

All magnets possess the property of pointing north and south when freely suspended, and the end which persistently points north is marked *N*, while the end which persistently points south is marked *S*. If you will observe the magnet used in the preceding experiment, you will see that one end is marked *N* and one end is marked *S*.

2. Bring the end of the bar magnet marked *N* toward the similarly marked end of the magnetic needle (Fig. 70). Is the needle attracted or repelled?

Bring the north (N) end of the bar magnet toward the S end of the magnetic needle. Is the needle attracted or repelled?

Make a similar experiment, using the south pole of the large magnet.

Tabulate results as follows:—

The N pole of the magnet	attracts or repels	the N pole of the magnetic needle.
" " " " " "	"	" S " " " " "

The S pole of the magnet	attracts or repels	the N pole of the magnetic needle.
" " " " " "	"	" S " " " " "

Do poles of like or unlike names attract each other?
Do poles of like or unlike names repel each other?

EXPERIMENT 90. OTHER RESPECTS IN WHICH AN ELECTRIC CURRENT IS LIKE A MAGNET

We have seen that a current-carrying wire is able to deflect a magnetic needle and to attract iron filings. If we can show experimentally that such a wire has lines of force, and in addition that it obeys the laws of magnetic attraction, we shall be justified in saying that a current-bearing wire is in most respects equivalent to a magnet.

For this purpose, we must have a strong current. The electricity furnished by cells, while strong enough for electric bells and for most laboratory purposes, is relatively weak. Elevators, electric lights, etc., require strong currents, and for this reason electricity is generated on a large scale in other ways. Most large buildings have their own electric plant and produce their own electricity, sending it from the generating room to distant parts of the building by means of insulated wires hidden in floors or walls.

1. In your laboratory desk are wires which connect with a central source of electricity. Attach the closely wound, insulated coils used in Experiment 86 to the desk source of electricity and see whether the ends of the coil affect the magnetic needle as the bar magnet did. That is, does one end of the coil always attract the N pole of the magnetic needle and repel the S pole? Does the opposite end of

the coil always repel the N pole of the magnetic needle and attract its S pole?

2. Slip a thick wire through a piece of paper or cardboard and attach the wire to the desk source of electricity. Sprinkle filings lightly on the card, and notice whether they assume any characteristic positions. If so, sketch roughly.

Have you seen, so far, any respect in which current electricity could not be considered equivalent to a magnet?

EXPERIMENT 91. THE PRINCIPLE OF THE MOTOR, OR ELECTRICITY AS A SOURCE OF MOTION

1. Suspend a light weight coil of wire (Fig. 71) between the poles of a horseshoe magnet. Does the coil assume any characteristic position, or will it remain where placed?

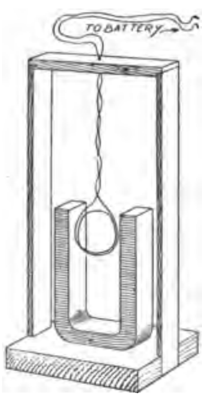


FIG. 71. — The coil rotates between the poles of the magnet.

2. Connect the terminals of the coil to an electric battery and note the result.

Since current flowing through a coil transforms the coil into a magnet for the time, can you suggest why the coil moved? Why did the coil finally come to rest?

3. We have seen that current transforms the coil through which it flows into a veritable magnet, with a N pole at one face and a S pole at the opposite face. The direction in which the current enters the coil determines which face of the coil shall be the N pole and which the S pole. ("General Science," page 335.)

Attach a piece of gummed paper to one terminal of your coil, and connect the coil to the battery in such a way that the marked end is connected with the copper strip and the opposite end with the zinc strip.

Determine whether the labeled end is a N or a S pole by testing with the magnetic needle.

If the marked end of the coil repels the N pole of the magnetic needle, what must be its polarity, N or S?

4. Now connect the coil with the battery in such a way that the labeled end is united with the zinc strip. On testing with the magnetic needle, do you find that the poles have changed faces?

If, at the instant that the coil comes to rest in (2), we could have reversed the direction of the current in the coil, what effect do you think it would have had upon the swing of the coil?

In a motor, electricity is applied, and motion results. To-day commercial sewing machines, mills, electric fans, trolley cars, and a host of other well-known inventions owe their efficiency, not to muscular energy, but to electrical energy.

EXPERIMENT 92. THE PRINCIPLE OF THE DYNAMO AND THE TELEPHONE

The Dynamo. — Connect a closely wound coil of wire to a galvanometer as shown in Figure 72. Is there any deflection of the galvanometer needle? Thrust a magnet into the coil. Does this cause a deflection? Withdraw the magnet from the coil. Does this cause a deflection? Allow the magnet to remain at rest within the coil. Does this cause a deflection?

What does a deflection of the galvanometer needle indicate?

State clearly how an electric current may be produced by the aid of magnets.

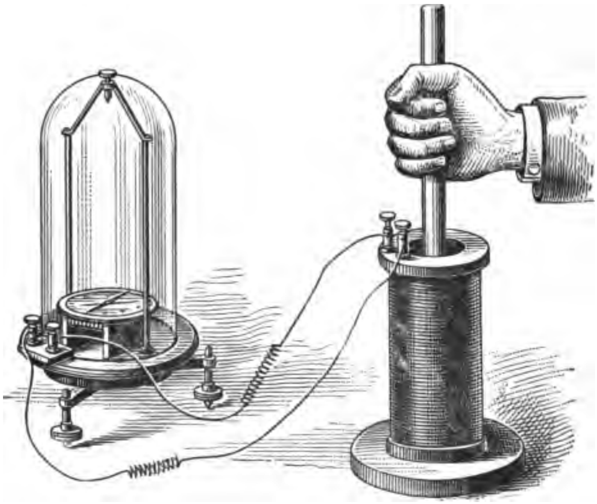


FIG. 72. — In the dynamo motion is supplied and electricity results.

The Telephone. — Place a magnet within a coil of wire which is attached to a galvanometer as before. Bring a piece of soft iron toward the magnet. Does the approach of the magnet cause a deflection of the needle? Withdraw the soft iron. Does the withdrawal of the magnet cause a deflection of the needle?

Why should the approach and withdrawal of the iron produce a current of electricity?

Explain how this principle is applied in the telephone.